VOLUME 31 NOVEMBER 1953 NUMBER 6

Canadian Journal of Botany

Editor: D. L. BAILEY

Published by THE NATIONAL RESEARCH COUNCIL
OTTAWA CANADA

CANADIAN JOURNAL OF BOTANY

(*Formerly Section C, Canadian Journal of Research*)

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PRELIMINARY STUDIES ON THE SEXUAL STAGE OF *RHIZOCTONIA SOLANI* KÜHN[1]

BY E. J. HAWN[2] AND T. C. VANTERPOOL[3]

Abstract

The perfect stage of a flax strain of *Rhizoctonia solani* Kühn was obtained fairly consistently on artificial media. In growth characters and morphological dimensions, it agreed closely with those of *Pellicularia filamentosa* (Pat.) Rogers, except that its sterigmata averaged three times as long (26μ). This latter character suggests close relationship to *Corticium praticola* Kotila. Single-basidiospore cultures differed among themselves and from the parent strain in morphology, cultural characters, growth rates, and pathogenicity on Royal flax. Some single-spore cultures produced the perfect stage, although preliminary pairings of sterile single-spore cultures remained sterile. This isolate is thus heterozygous and homothallic. There appear to be 12 chromosomes in the diploid nucleus in the basidium. The mature basidiospore is predominantly uninucleate; occasionally a binucleate basidiospore is observed. Germination is by repetition on plain agar, or by germ tubes on rich media. Those basidiospores which germinate by repetition are commonly uninucleate and give rise to uninucleate secondary basidiospores. Basidiospore discharge is by the drop excretion mechanism. To determine the identity of the flax strain, it will be necessary to produce the perfect stage of the flax strain on natural substrates or the perfect stage of *P. filamentosa* on artificial media.

Introduction

Rhizoctonia solani Kühn is one of the most widely distributed of all naturally inhabiting soil pathogenic fungi. Its many recognizable strains shows that it is a complex species. The increasing number of publications dealing with diseases caused by this fungus in recent years and its extremely wide host range testify to its economic importance. Full historical accounts of the nomenclature and taxonomy of this fungus have been given by Kotila (7 and 8). It was first described in 1858 by Kühn (9) as a pathogen of potato. Its perfect stage was not known until 1891, when Prillieux and Delacroix (11) reported it as *Hypochnus solani*, but it was not until 1904 that Rolfs (13) proved that the perfect stage was a *Corticium*. For many years the perfect stage has been referred either to *C. vagum* var. *solani* Burt or to *C. solani*

[1] *Manuscript received July 6, 1953.*

Contribution from the Laboratory of Plant Pathology, University of Saskatchewan, Saskatoon, Sask. This study was carried out with the assistance of a grant-in-aid of research from the National Research Council.

[2] *Formerly Research Assistant, University of Saskatchewan and at present Agricultural Research Officer, Laboratory of Plant Pathology, Lethbridge, Alta.*

[3] *Professor of Plant Pathology, University of Saskatchewan.*

[The September number of this Journal (Can. J. Botany, 31: 515-697. 1953.) was issued September 30, 1953.]

(Prill. and Del.) Bourd. and Galz. In 1943, Rogers (12) recommended that the fungus with its various synonyms be included in the new combination *Pellicularia filamentosa* (Pat.) Rogers.

Great difficulty has been experienced in obtaining and controlling the formation of the sexual stage of *R. solani* in artificial culture. Müller (cited by Kotila, (7)) in 1923, Ullstrup (15), Exner and Chilton (4), Kotila (8), and Carpenter (3) have met with varying degrees of success in obtaining the perfect stage of various strains of *R. solani* in culture by applying the principle of growing the fungus on a rich medium and then transferring it to a weaker one or to water agar. Improvements in the method are highly desirable so that good control in the production of the perfect stage can be regularly obtained.

Kotila (7) found that formation of the perfect stage of *Corticium praticola* Kotila, a fungus very closely related to *P. filamentosa*, could be fairly well controlled on artificial media. He was thus able to make a rather comprehensive study of single basidiospore isolates of this species.

While carrying out investigations on the seedling blight and root rot of flax (*Linum usitatissimum* L.) caused by *R. solani*, certain strains, particularly RF6-20, were found to produce the perfect stage fairly consistently in culture. The main purpose of these cultural and cytological studies, made on the perfect stage and supplemented by pathogenicity tests on the single basidiospore cultures, was to gain more information on the factors involved in the sexuality of the fungus and on the cause of the well-known variability of different isolates. The work reported here was conducted mainly with flax strain RF6-20.

Method of Inducing Hymenial Formation

The usual method of growing the fungus on rich nutrient media and then transferring it to water agar was used to induce hymenial development. Transfers were from approximately 30-day-old malt agar or potato-dextrose agar test tube cultures to Petri dishes containing thin pourings of 2% water agar. Inocula from 4-, 7-, and 14-day-old cultures were tried, but they tended to give too strong mycelial and sometimes sclerotial growth. One per cent water agar was not as satisfactory as 2%, as the basidia were formed below the surface of the former where they failed to produce spores. The inoculated plates were placed under a bell jar in diffuse light in front of a north window. A temperature range of 19° to 25° C. and a relative humidity of approximately 70-80% gave the best results.

Hymenial Development

Under these conditions there was surprisingly good vegetative hyphal development on the surface of the agar. Hymenial development was observed in fertile strains within 14 to 21 days, usually 17. The radiating hyphae had produced short side branches which bore clusters or cymes of basidia at their tips (Fig. 6). Each mature basidium bore two to four long tapered sterigmata

terminated by basidiospores (Figs. 1, 3, 4). The basidia were simple, clavate, with an average measurement of 13.4 × 8.1μ (Fig. 6). The sterigmata were broadest just above the basidia and tapered uniformly at maturity to a narrow point of attachment with the apiculus of the basidiospore. There were two to four, usually four, sterigmata to each basidium. They averaged 26.6μ (20.0-30.0μ) × 4.7μ (4.0-5.1μ) at the widest point. Sterigmatic and basidiospore development followed the usual course as in *Corticium* and basidiomycetes generally. Following spore discharge, the basidia and sterigmata gradually collapsed (Fig. 5). The basidiospores are thin-walled, smooth, hyaline, and apiculate (Fig. 7), with an average measurement of 8.9 × 5.5μ. The usual method of violent spore discharge by the drop excretion mechanism which is common in the basidiomycetes has been observed by both authors. Germination may be by repetition on water agar or by a germ tube on nutrient agars. Where germination is by repetition, the sterigma often arises from the apiculus and its length is approximately twice that of the basidiospore from which it arises (Figs. 10 and 11). A secondary basidiospore develops at its apex. Where germination is by a germ tube, growth usually begins at a point approximately opposite the apiculus (Figs. 8 and 9). The sporeling develops rapidly producing mycelium with the usual characteristics of a *Rhizoctonia* culture obtained from diseased tissue or from sclerotia.

Single-spore Isolation and Study

Petri plates containing the fruiting cultures of strain RF6-20 were inverted over the bottoms of potato-dextrose agar plates for periods varying from 15 min. to 24 hr. Care was taken to maintain favorable temperature and humidity ranges. Usually seven hours exposure was found most satisfactory. The seeded plates were kept at laboratory temperature for 48 hr.

Following incubation each Petri dish was inverted on the microscope stage and searched for germinated basidiospores. Suitably isolated sporelings were marked by means of a marking objective. The plates were then opened and small agar disks containing the sporelings were removed with the aid of a cutting device fitted over the 10 power objective. The transferred disks were then examined to make certain that there was only one sporeling to each disc. Only 16 of the 50 sporelings transferred to tubes of potato-dextrose agar continued to grow. This experience was similar to that encountered by Kotila working with *C. praticola* (7) and with *P. filamentosa* (8).

Growth Rates of Single-spore Cultures

Comparative growth rates of the single-spore cultures together with the parent strain RF6-20 were conducted on potato-dextrose agar in growth-rate tubes after the method employed by Newton (10). The tubes were incubated at 25° C. ± 0.5° C. Measurements of 10 consecutive linear growth increments were made at 24-hr. intervals beginning on the third day. The

results are presented in Table I, columns 1 and 2. It will be seen that there is a wide divergence in the growth rates of the single-spore cultures. The range extended from practically nothing as in single-spore cultures, Rb 19 and Rb 20 to 12.5 mm. as in culture Rb 6, which was virtually the same as that of the parent strain RF6-20. Cultures Rb 10 and Rb 14 grew extremely slowly.

TABLE I

LINEAR GROWTH RATES IN MILLIMETERS IN 24 HR. AT 25° C. AND PATHOGENICITY TESTS ON FLAX OF SINGLE-BASIDIOSPORE CULTURES OF STRAIN RF6-20 OF *R. solani*

Culture	Growth rate, mm.	Disease effect
RF6-20 (parent strain)	13.0	Total killing
Rb 1	10.9	Severe
Rb 2	10.6	Severe
Rb 3	11.7	Severe
Rb 4	12.0	Severe
Rb 5	11.3	Moderate
Rb 6	12.5	Trace
Rb 7	9.7	Severe
Rb 8	11.3	Trace
Rb 9	12.2	Total killing
Rb 10	3.4	None
Rb 11	9.7	Total killing
Rb 12	9.5	Severe
Rb 13	12.0	Severe
Rb 14	3.0	None
Rb 19	Trace	Trace
Rb 20	Trace	None

Pathogenicity Tests of Single-spore Cultures

Comparative pathogenicity tests on Royal flax of the single-spore cultures were carried out in Petri dishes lined with moist filter paper. The disease readings, taken on the fourth day, are presented in Table I, column 3. The results showed a range of pathogenic ability from nonpathogenic to total blighting or damping-off of the flax seedlings. Marked differences in cultural characteristics, in growth rates, and in pathogenicity of the single-basidiospore cultures, all indicate that the parent culture RF6-20 is heterozygous.

Hymenial Development in Single-spore Cultures

Since strain RF6-20 showed no clamp connections, the single-spore cultures were subjected to tests on 2% water agar to determine whether they would produce basidiospores. This should give a more positive indication of the sexual nature of the parent strain. Table II, column 2, shows the results obtained.

The presence of basidia in 9 of the 16 single-spore cultures, and more specifically the production of basidiospores in 4 of the 9, gave strong evidence of a homothallic state. The fruiting structures conformed with those found

on a parent culture. The dikaryotic condition arises within the single-spore culture; but the possibility that it can be initiated by conjugation of thalli of opposite sex arising from sterile single-spore cultures has not been disproved.

TABLE II

GROWTH OF SINGLE-SPORE CULTURES WHEN GROWN ALONE AND WHEN PAIRED WITH SINGLE-SPORE CULTURE Rb 10 UNDER CONDITIONS FAVORING DEVELOPMENT OF THE PERFECT STAGE

Single-spore culture	Results when grown alone	Results when paired with Rb 10
Rb 1	Basidiospores	Basidia
Rb 2	Basidia	Basidia
Rb 3	Basidiospores	Basidia
Rb 4	Basidia	
Rb 5	Basidia	Basidia
Rb 6		
Rb 7		
Rb 8		
Rb 9		
Rb 10		
Rb 11	Basidiospores	Basidiospores
Rb 12	Basidia	
Rb 13	Basidiospores	
Rb 14	Basidia	Basidia
Rb 19		
Rb 20		

Blanks indicate no hymenial development.

Single-basidiospore Matings

A small-scale experiment was set up to determine whether hymenial development would result from matings or pairings in those single-spore cultures previously found to be sterile.

Single-spore culture Rb 10 was chosen as the common member of the mated pairs because of its lack of pathogenicity on flax, its extremely slow rate of growth at 25° C., and its failure to produce either basidia or basidiospores. Pairings were made from 30-day-old potato-dextrose agar tube cultures to Petri dishes of 2% water agar as follows: Rb 10 was paired individually with single-spore cultures Rb 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 19, and 20. All plates kept under environmental conditions favoring hymenial development were examined daily. Basidia and basidiospores developed in the mated pair Rb 10 × Rb 11, basidia only were formed in the mated pairs Rb 10 × Rb 1, Rb 10 × Rb 2, Rb 10 × Rb 3, Rb 10 × Rb 5, and Rb 10 × Rb 14, while the remaining pairs remained sterile. A comparison with the results in Table II shows that all matings that produced basidia or basidiospores had reacted in a similar manner when tested separately. Culture Rb 10 had no apparent influence on inducing the perfect stage in any of the single-spore cultures which did not produce basidiospores when cultured alone.

Taxonomic Relationships

The numerous isolates from diseased flax seedlings of the fungus under investigation can readily be separated into groups according to various asexual characters. The value of such a classification would be questionable considering the ease with which the fungus segregates in nature. Reliance should be placed almost wholly on the characteristics of the perfect stage. Using these criteria, ***Rhizoctonia*** RF6-20 is seen to be closely related to *Corticium praticola* (7) and to *Pellicularia filamentosa* (12). The features of the perfect stages of these three forms have been assembled in Table III to facilitate comparison.

TABLE III

COMPARATIVE CHARACTERS AND BASIDIOSPORE MEASUREMENTS OF *Corticium praticola*, *Pellicularia filamentosa*, AND FLAX *Rhizoctonia* RF6-20

	Costicium praticola	*Pellicularia filamentosa*	Flax strain RF6-20
Average basidial dimensions in microns	15.6 × 6.5	12-18 × 8-11	16.8 × 8.1
Average length of sterigmata in microns	18.8	5.5-12(-20)	26.6
Average number of sterigmata per basidium	3	4	4
Average basidiospore dimensions in microns	7.7 × 5.2	7-12.5 × 4-7	8-9 × 5.5
Basidiospore germination	Repetition	Repetition or germ tube	Repetition or germ tube

The extreme length of the sterigmata of *Rhizoctonia* RF6-20 sets it apart from the described species. The ratio of the average length of the sterigmata of *Rhizoctonia* RF6-20, *C. practicola*, and *P. filamentosa* is roughly 3 : 2 : 1. In other characters RF6-20 and *P. filamentosa* are in close agreement. The dimensions of the basidiospores are slightly smaller and the average number of sterigmata to each basidium is one less in *C. praticola* than in the other two forms. If extreme difference in length of sterigmata be considered of sufficient importance in the delimitation of species in this genus, then RF6-20 should be regarded as a distinct species or at least more closely related to *C. praticola* than to *P. filamentosa*. The various dimensions recorded for *P. filamentosa* are from material on natural substrata, while those for *C. praticola* and RF6-20 are from material on artificial media. This difference was recognized by Kotila (7) and Rogers (12) in comparing *C. praticola* and *P. filamentosa*.

Cytological Investigations

The moderate success achieved in obtaining the perfect stage of *R. solani* strain RF6-20 in culture paved the way for an investigation of the nuclear cycle of the fungus.

A search for pertinent literature failed to reveal any previous work of a

cytological nature on the perfect stage of *R. solani*. The cytological investigations reported here were accordingly undertaken in an attempt to gain long needed information on the nuclear cycle of the fungus.

Methods

The method previously described for obtaining hymenia on 2% water agar was used. As soon as cymes of basidia and basidiospores were observed in a Petri dish culture, selected squares were cut from the agar substrate and placed in the fixing solution in a corked shell vial. Bouin's formalin-acetic-alcohol, and modified Carnoy's (14) fixatives were tried. Of these, modified Carnoy's solution gave the best results since it removed most of the oil globules from the cytoplasm. The most satisfactory results were obtained with 18 to 24 hr. fixation. Of the stains tried, Haidenhain's hematoxylin was found to give good differentiation of nuclei in mycelial cells, whereas a modification of Johnson's Feulgen method (6) gave the best results in staining the nuclei in the basidia and basidiospores probably because they were more commonly in an active state of division. The nuclei, when prepared by the Feulgen method, appeared bluish black when examined under an ordinary compound microscope. For further detailed study of stained preparations a phase microscope was used. The latter instrument proved most useful in this work since the nuclei of *R. solani* are extremely small and are thus often hard to distinguish from other stainable cell inclusions.

In some preparations, it was possible to observe the chromosomes. These are extremely small, so tiny in fact that it is impossible to tell with any degree of certainty whether the chromosomes are univalent or bivalent. However, there appear to be six chromosomes in each mycelial nucleus (Fig. 2).

Mycelia

Stained preparations of the mycelium of strain RF6-20 show that the terminal cells of the hyphae are multinucleate (Figs. 12 and 13). Both cells figured have eight nuceli; however, this number is probably not constant. Since clamp connections are not present and since the nuclei which are proximal to the base of the cell tend to be paired (Fig. 13), it seems probable that these pairs are progressively cut off by newly formed septa as the hypha elongates, giving the binucleate condition found in older cells (Figs. 14 and 15).

Basidia

The hymenia develop on short side branches arising from the main hyphal trunks. The terminal cell of each branch proliferates into short basidial cells whose cytoplasmic density is marked since it stains quite deeply in comparison with that of older mycelial cells. These young basidia are binucleate (Figs. 16 and 17) with the nuclei being in no definite position or orientation. The nuclei soon come together (Figs. 18 and 19) and fuse to form the fusion nucleus (Figs. 20 and 21). The nucleus then enlarges without apparent swelling of the basidium and develops a definite chromatin content as suggested by the

reaction to the Feulgen stain (Figs. 22 and 23). This appears to be the prophase leading to meiosis I in the basidium. Many of the nuclei show deeply stained bodies with chromatin strands attached and radiating outward (Figs. 23 to 25). This body or nucleolus later disappears and the chromatin strands shorten and take on the appearance of chromosomes (Figs. 26 and 27). Good evidence of chromosome pairing is shown in Figs. 28 to 30, with Fig. 29 presenting a diakinesis view of what seems to be six bivalents. A side view of metaphase is shown in Fig. 28 and anaphase configurations are shown in two adjacent basidia in Fig. 30. The first nuclear division is followed almost immediately by a second division resulting in the formation of four nuclei (Fig. 31). These are probably haploid although insufficient definite chromosome counts could be made on nuclei in the basidia to give more than an indication. By the completion of this last nuclear division sterigmata formation has usually begun (Figs. 31 and 32). Ordinarily, four such structures arise from the apical area of the basidium and elongate. One nucleus enters each sterigma and migrates towards the tip (Figs. 33 to 35). Following the development of a basidiospore at the tip of each sterigma, the single nucleus migrates from the sterigma into the basidiospore (Fig. 36). At or near maturity, the opening between the apiculus of the spore and the sterigma appears to become closed.

Basidiospores

Following the discharge of the basidiospores, sterigmata and basidium gradually collapse. Maturation of the basidiospores on any one basidium often varies. This is borne out by the fact that staining sometimes reveals the presence of a nucleus in some, but not all, of the basidiospores on one basidium (Fig. 37). Mature basidia and basidiospores are shown in Fig. 36.

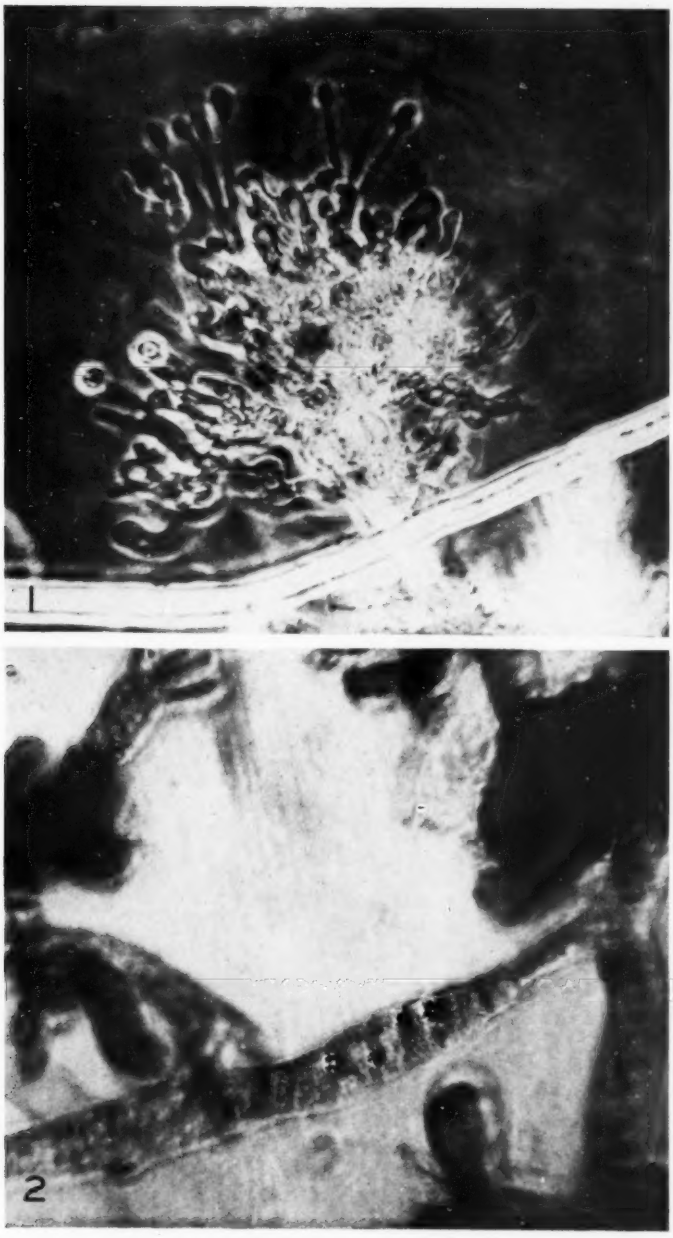
Germination

Basidiospores which germinate on plain agar do so by repetition (Figs. 38 and 39). The secondary spore is usually uninucleate (Fig. 40), though occasionally the binucleate condition has been observed (Fig. 43).

In some cases, a basidiospore will germinate by repetition while still attached to its sterigma (Fig. 41). This may be attributed to too high a humidity which is not conducive to violent basidiospore discharge. During the early stages of germination the spore is uninucleate (Fig. 45); however, the binucleate condition has been found on rare occasions (Figs. 42 and 44). The morphological features of direct germination which were obtained earlier in these investigations are shown in Figs. 8 and 9.

FIG. 1. *Rhizoctonia solani* alfalfa strain RF6-20. A phase photomicrograph showing a main hyphal trunk bearing a cyme of basidia and fully developed fruiting structures. Magn. × 560.

FIG. 2. *Rhizoctonia solani* alfalfa strain RF6-20. A phase photomicrograph of a hyphal cell showing nuclei and chromosomes. Magn. × 950.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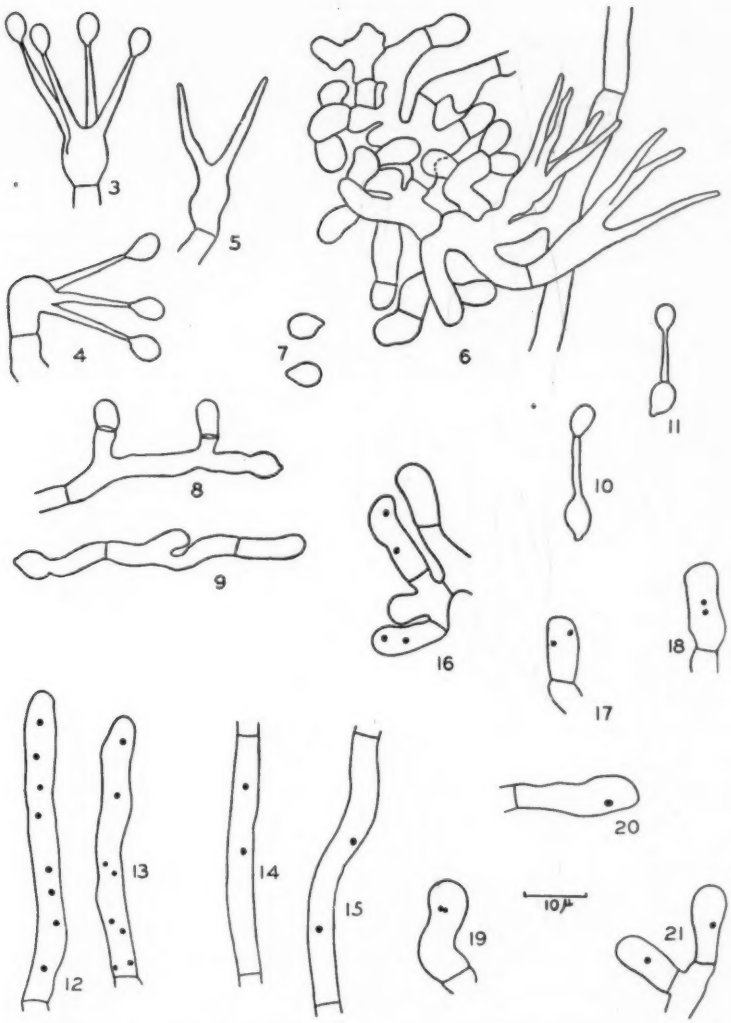
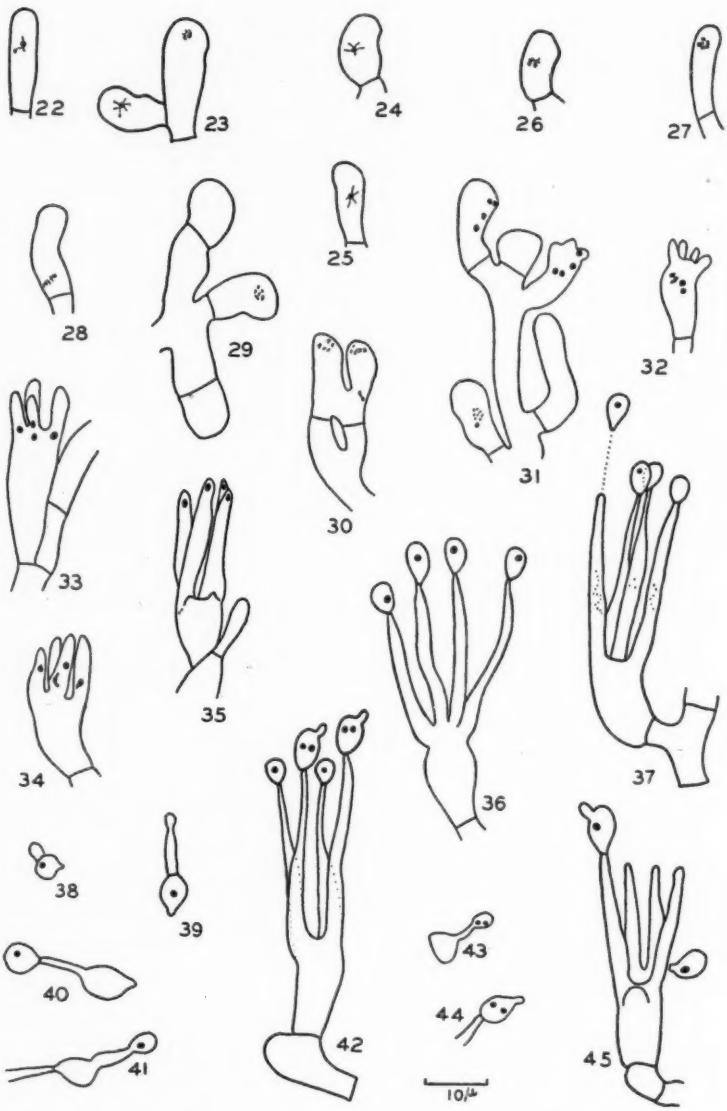


FIGS. 3 to 21. *Rhizoctonia solani* alfalfa strain RF6-20. Fig. 3. A mature basidium with four sterigmata and basidiospores. Fig. 4. A basidium with three sterigmata. Fig. 5. Collapsing basidium following basidiospore discharge. Fig. 6. A typical basidial cyme. Fig. 7. Basidiospores. Figs. 8 and 9. Direct germination. Figs. 10 and 11. Germination by repetition. Figs. 12 and 13. Multinucleate condition of terminal hyphal cells. Figs. 14 and 15. Binucleate condition of ordinary hyphal cells. Figs. 16 and 17. Binucleate basidia. Figs. 18 and 19. Nuclei about to fuse. Figs. 20 and 21. Fusion nuclei in basidia. Figs. 3 to 11 drawn from unstained material; Figs. 12 to 15 stained with Haidenhain's haematoxylin; and Figs. 16 to 21 stained by the Feulgen method.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Discussion

The method used in producing a fertile hymenium of *Rhizoctonia solani* flax strain RF6-20 in culture shows promise as an aid in the classification of the forms which are ordinarily grouped under the composite species *Rhizoctonia solani* Kühn and which do not normally fruit *in vitro*. It may prove of value in the study of closely related Basidiomycetes. Through an extensive study of the fruiting stage of such fungi, it should be possible to separate forms hitherto considered indistinguishable in the vegetative stage, or conversely, to retain in one species strains with striking differences in vegetative characters. So long as a standard method of rearing the fungi is used the chance of complicating differences in the morphology of key structures would be largely eliminated.

This study of the nuclear cycle shows that this fungus is basically similar to that of other members of the class, more especially those included in the Tremellaceae and the Thelephoraceae.

The growing tips of the mycelium are multinucleate (Figs. 12 and 13) and older cells are binucleate (Figs. 14 and 15). This is similar to the condition found by Biggs (1) in *Peniophora ludoviciana* Burt where the cells of the diploid hyphae are initially multinucleate but finally develop into binucleate clamp-bearing cells. However, strain RF6-20 is devoid of clamp connections.

The means by which the mycelium becomes binucleate is still not known. No evidence was found which would support Buller's (2) belief that such a state could be brought about by migration of nuclei through the central pores of the septa. Instead, it would appear from the position of nuclei in the hyphal tips that cells of the mycelium become binucleate as a result of new septa cutting off pairs of nuclei and with nuclear division in the terminal cell keeping it in a coenocytic state as long as the substratum supports new growth.

The presence of two nuclei in young basidia (Figs. 16 and 17) and their subsequent fusion (Figs. 20 and 21) again shows that the nuclear cycle is comparable to that found in other Basidiomycetes (1, 2, 5, 14, 16).

Variability shown by the single-spore cultures obtained from RF6-20 (Table I) supports the findings and observations of Exner and Chilton (4) and Kotila (8). Their belief that such variabilities are the result of segregation in the basidial stage is substantiated by the observed sequence of nuclear activity; namely, conjugation of two nuclei in the basidium followed by two

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FIGS. 22 to 45. *Rhizoctonia solani* alfalfa strain RF6-20. Figs. 22 to 25. Nucleolus-like bodies with radiating chromatin fibers. Figs. 26 and 27. Chromosomes. Fig. 28. Side view of metaphase. Fig. 29. Diakenesis in prophase showing six chromosomes. Fig. 30. Anaphase in two adjacent basidia. Fig. 31. The two basidia at top with four haploid nuclei. Basidium at right has begun to form sterigmata. Fig. 32. Sterigmata elongating. Figs. 33 to 35. Stages in the migration of nuclei into the sterigmata. Figs. 36 and 37. Mature basidia bearing uninucleate basidiospores. Fig. 38. Germinating basidiospore. Fig. 39. Early stage in secondary basidiospore formation by repetition. Figs. 40 and 41. Uninucleate secondary basidiospore. Fig. 42. Basidium with germinating basidiospores *in situ*. Figs. 43 and 44. Binucleate secondary basidiospores. Fig. 45. Uninucleate basidiospore germinating *in situ*. Drawings made from material stained by the Feulgen method.

nuclear divisions giving four nuclei (Figs. 31 and 32), one of which migrates into each of the four basidiospores (Figs. 33 to 36). Thus the basidium must be the site of segregation of hereditary factors leading to the formation of variable types. This segregation does not appear to include those factors responsible for the determination of sex since here, as in the case of *Corticium praticola* (7), some single-spore cultures form the perfect stage without benefit of mating. Thus *R. solani* strain RF6-20 can be regarded as homothallic. Failure of some sporelings to fruit is probably due to the suppression or loss of the factor responsible.

The basidiospores are predominantly uninucleate with the single nucleus migrating into the secondary spore during the process of germination by repetition. This phase of the nuclear cycle is similar to that found by Whelden (16) in *Protodontia* and by Jackson (5) in *Herpobasidium filicinum*. However, binucleate basidiospores of RF6-20 are occasionally found. Since germination of these spores may be by repetition or by mycelium there is a possibility that such spores would normally germinate directly but, because of a lack or absence of nutriment they produce secondary spores for survival. It is notable that the binucleate condition was observed only in spores which had begun to form germ tubes. This would indicate that a single mitotic division, similar to that reported by Jackson (5), precedes germination by mycelium and initiates the multinucleate state observed in meristematic hyphal cells.

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STUDIES ON THE FLAGELLA OF ALGAE

III. ELECTRON MICROGRAPHS OF *CHLAMYDOMONAS MOEWUSII*[1]

By R. A. Lewin[2] and Josephine O. Meinhart[3]

Abstract

Each flagellum of *Chlamydomonas moewusii* appears to originate at a basal granule beneath the papilla. The intact flagellum is composed of:

(*a*) a central axis, consisting of 9 – 11 dense fibrils, 450Å wide, fused laterally to form a hollow cylinder;

(*b*) a less dense component, possibly fluid, within the axial cylinder; and

(*c*) a sheath of less dense material, surrounding the axial cylinder, and clearly delimited by a superficial membrane which is believed to be semipermeable. Mating-type specificity seems to reside in this component, since it is involved in the agglutination reaction which precedes copulation.

The flagellum terminates in a mucro 0.3 – 0.5 μ long. There is no whiplash filament. Certain structural changes, due to disorganization, disruption, or disintegration of the flagellar components, are described and figured. Possible modes of action of the flagella in cell propulsion are briefly discussed in the light of flagellar structure as revealed by electron microscopy. No structural differences have been observed between the flagella of paralyzed mutants and of wild-type cells.

Introduction

The cilia and flagella of protozoa and of such motile cells as spermatozoids and algal zoospores are 0.25 – 0.5 μ wide,* which is of the same order of magnitude as the shortest wave length of light in the visible range. Flagella can therefore be seen under the microscope, but are beyond the limits of critical definition. On the other hand, they are of the order of size most suited for examination by electron microscopy, and a number of such studies have already been undertaken (4, 18, 38, 37, 20, 5, 10, 12, 7, 15, 33, 34, 35, 6, 19, 28, 29, 30, 31, 11, 39, 2).

Observations of a variety of flagellated and ciliated cells, such as those of diverse protozoa, ctenophores, fungi, and algae; fern antherozoids; and the spermatozoa of many animals (e.g. spiders, echinoderms, fish, birds, and mammals) have revealed a close similarity in the structure of the flagella or cilia. In many cases the axis has been observed to exhibit a tendency to split into 9 – 12 strands or fibrils (26) which presumably constitute its main structural components. This remarkable uniformity of pattern indicates that a more detailed study of the structure and activity of the flagella of any one organism might reveal features common to others, and yield clues as to the mode of action of these organelles.

In several respects, green flagellates provide the most favorable material for such study, and the ease with which *Chlamydomonas* can be cultured in

[1] *Manuscript received July 6, 1953.*

Contribution from the Osborn Botanical Laboratory and the Department of Physiological Chemistry, Yale University, New Haven, Conn.

[2] *Present address: National Research Council of Canada, Maritime Regional Laboratory, Halifax, N.S.*

[3] *Department of Physiological Chemistry, Yale University, New Haven, Conn.*

* *All dimensions given in this paper refer to magnitudes as measured in electron micrographs of desiccated preparations, and no adjustment has been made for flattening or shrinkage.*

simple media renders it peculiarly suited for this purpose. A general account of flagella in *Chlamydomonas moewusii* has already been published (23). The following observations, supported by a total of over 500 electron micrographs, serve to supplement this preliminary account, and to provide a basis for further study of flagellar motility in normal cells, and in cells in which motility has been physiologically or genetically impaired (Lewin, in preparation).

Materials and Methods

The strains of *Chlamydomonas moewusii* Gerloff used in these studies were isolated from greenhouse sand by Dr. L. Provasoli in 1948.

Cells were as a rule cultivated in a liquid medium containing:

$Ca(NO_3)_2 \cdot 4H_2O$	1.0 gm. per liter
$MgSO_4 \cdot 7H_2O$	0.2 gm. per liter
K_2HPO_4	0.2 gm. per liter
Trace elements (Fe, B, Mn, Zn, Cu, Mo)	

In certain experiments the medium was diluted $\times 1/10$, or supplemented by 1.0 gm. per liter anhydrous sodium acetate; but the composition of the culture medium was not observed to affect the structure of the flagella in any way.

Cultures were continuously illuminated by white fluorescent tubes at light intensities of 200 – 450 ft-c. in a chamber maintained at 23° C.

For the examination of intact flagella, the cells were fixed with 0.1% osmium tetroxide, washed in three changes of distilled water, and mounted by drying on collodion films supported by nickel wire-mesh grids. They were dried at room temperature. (Attempts to improve the method by lyophilizing were not successful.) Preparations were shadowed with palladium at an angle of 7:1, thereby considerably improving definition under the electron microscope.

Detached flagella were obtained from washed living cells following treatment by various irritants such as dilute acetic acid, ammonia, or ethanol. The cell-bodies were removed by low speed centrifugation (e.g. 350 gm., 3 min.) and the flagella were then mounted and prepared for examination as above. Concentration of flagella by stronger centrifugation (e.g. 5000 gm., 30 min.) was possible, but was usually unnecessary.

In the preparation of sections, the living cells were first concentrated in a Sharples centrifuge, and were washed once in distilled water. The flagella were then detached by the addition of alcohol (to a final concentration of 10%), the cell-bodies were removed by low speed centrifugation, and the flagella concentrated and compacted by further centrifugation of the supernatant. The pellet so formed was fixed with osmium tetroxide, washed twice with distilled water, and sectioned according to the method described by Banfield *et al.* (3). Briefly, this consisted of transferring the flagella by graded changes through alcohol into a mixture of methyl and butyl metacrylate. 2-4 Dichlorobenzoyl

peroxide was added to the methacrylate mixture, which was then allowed to polymerize by incubation at 60° C. for 18 – 24 hr. The resulting plastic block was sectioned with a glass cutting edge in a specially adapted microtome set at 0.05 μ.

Observations

(*a*) *Flagellar Attachment*

The cells of *C. moewusii* are ovate or oblong, 8 – 12 μ in length, with a low transverse ridge or papilla at the anterior end. The two flagella originate at the ends of this ridge, near its base. Although the cell bodies are generally quite opaque to the electron beam, it has in some cases been possible to discern within the wall a pair of blepharoplasts, appearing as spheroidal granules 3000 Å in diameter, one at the base of each flagellum where it adjoins the cell cytoplasm (Fig. 2).

(*b*) *The Flagellar Sheath*

In mounts of intact cells, the flagella are seen to be composed of two main components, a dense axial cylinder or core, and a less dense but clearly defined sheath. The membrane surrounding the sheath apparently may be inflated (as observed in *Pylaiella* and *Sphagnum* by Manton (26, 30, 31)) or disrupted with dissolution of the sheath in the aqueous medium, exposing the more resistant fibrous material of the axis (Fig. 4). The sheath membrane is believed to be semipermeable, as indicated by the following observations.

(i) Plasmolysis of cells results in an inhibition of motility (Lewin, unpublished), as has also been observed in *C. eugametos* by Lothring (25), and motility is restored on recovery from plasmolysis.

(ii) The flagella become detached when cells are treated with irritants such as ethanol. In 10% alcohol the detached flagella appear relatively unchanged, whereas in preparations treated with 20% alcohol they usually appear as discoidal sacs, in each of which the axial cylinder is coiled in a flat spiral within the matrix, which may retain its clearly defined margin (Fig. 10). Intermediate stages with less coiling, in which the axis is only looped at one end, are also frequent (Figs. 8, 13). Similar effects are occasionally observed in flagella still attached to *Chlamydomonas* cells, and have also been described in Euglena by Hamburger (16). Possibly they result from the inflation of the matrical material by the rapid entry of alcohol through the membrane, the internal volume increasing while the membrane retains its minimum area, and the axial cylinder being constrained to coil within it. Disruption of the matrical membrane may occur at the moment of drying, leaving the coiled flagellar axis in a pool of matrix residuum (Fig. 11).

Vesicles of this sort have been observed on the cilia of infusoria (1) and on the flagella of fungal zoospores (36, 21, 17), as well as in *Chlamydomonas* and *Polytoma* spp. (13, 8, 9, 22). Both Desroche and Korschikov, though limited to light microscopy, correctly described flagella as comprising an axial core and a less dense peripheral zone, and interpreted vesicle formation (illustrated

particularly well by Desroche, Figs. 28 – 30) as an aggregation or coiling of the axis within the inflated sheath membrane. It may be noted that the phenomenon is usually observed in degenerate cells in which the activity of the contractile vacuoles is presumably reduced, with consequent impairment of the osmoregulatory mechanism.

The flagella are intimately concerned with the process of mating (23) in which, for a period of a few minutes, cells of opposite mating type are held together solely by the flagella. It can be seen in electron micrographs of cells in mating suspensions that this activity resides in the flagellar sheaths, which develop the property of intersexual agglutination in this phase. Pairing is initiated at the tips of the flagella (Fig. 3), and proceeds proximally. Then, after a protoplasmic bridge has joined the cytoplasts (Fig. 6), the flagella disengage, this process again commencing at the distal ends (Fig. 5). It may be noted that in both partners the sheath membrane remains intact or is restored after the flagella separate (Fig. 7), but that the flagella of only one of the partners remain fully active between copulation and cytogamy (23).

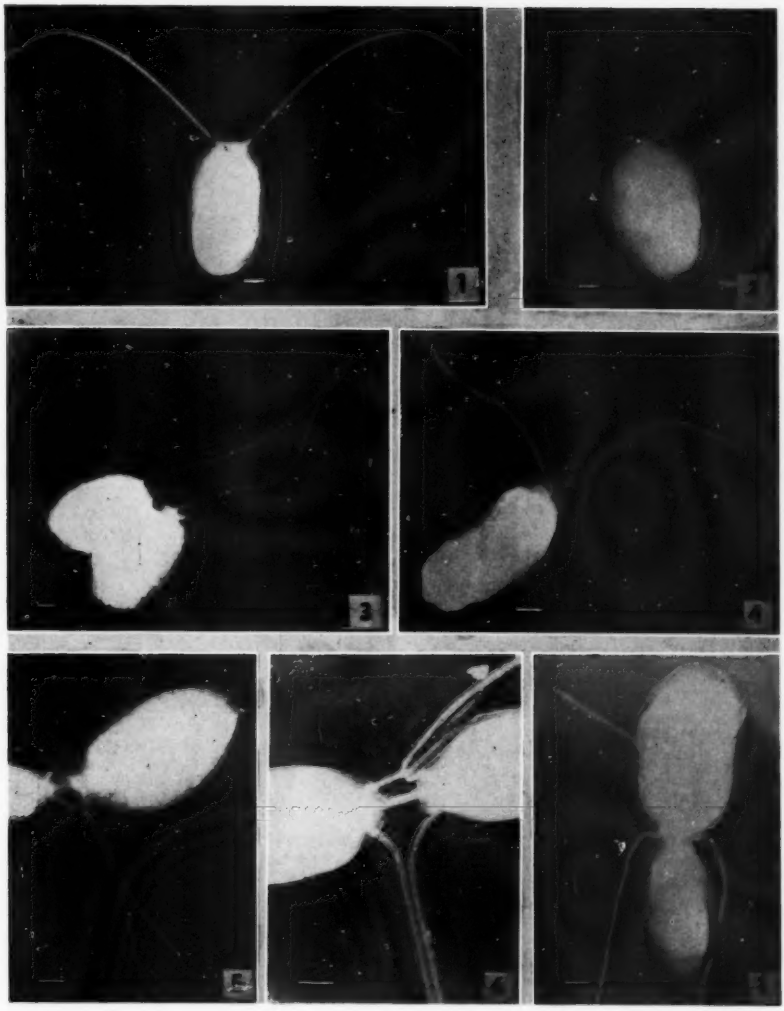
In the region of the flagellar apex, there has frequently been observed a characteristic agglomeration of the matrical material, which becomes associated into globules about 150 – 200 Å in diameter (Fig. 15). If this is not an artefact, as it well may be, one is tempted to assume that it represents the "stickiness" of the flagellar tips in the mating condition; but there is no evidence to support this view.

A dense granule (ca. 4500 × 1500 μ) has occasionally been observed in the sheath zone of otherwise intact flagella, flanking the axial cylinder (Figs. 1, 6). Its nature is unknown.

(*c*) *The Flagellar Axis*

Within the sheath, a dense cylindrical axis, 2500 Å in diameter, extends the full length of the flagellum. It occasionally shows transverse banding (cf. *Chlamydomonas* sp. (40); *Chilomonas* (6); *Paramecium* (20); *Arbacia* sperm (18); *Olpidium*, *Saprolegnia*, *Sphagnum* (30, 31)) with a regular period of 1000 Å (Figs. 20, 21), and also may exhibit traces of longitudinal striation. In disorganizing flagella, the axis tends to dissociate into 9, 10, or 11 component fibrils, each an untapered strand 450 Å wide. Manton *et al.* (28, 29, 30) have demonstrated, in such unrelated organisms as ferns, mosses, fungi, and algae of several phyla, the presence of nine stouter and two more tenuous fibrils in the flagellar axis, but no such regular differentiation has been observed in the flagella of *Chlamydomonas*. No suggestion of helical coiling has been observed, except in one case (Fig. 23), which in appearance is reminiscent of the fern cilia illustrated by Manton and Clarke (28).

In partially disintegrating flagella, it can be seen that the fibrils are arranged in the form of a hollow cylinder (Fig. 17), which may split longitudinally into a wide ribbon (Fig. 16), or be further lacerated into narrower bands or into the individual fibrils (Figs. 18, 19). In sectioned flagella, the sheath is lost in the course of preparation, but the axis is still recognizable as a hollow



All preparations (except Fig. 12) shadowed with Pd at angle 7 : 1. Scale shown in each figure, approximately 1μ.

FIG. 1. Intact cell of *Chlamydomonas moewusii*. FIG. 2. Cell showing basal granules. FIG. 3. Cells initiating pairing; tips of flagella adhering. FIG. 4. Cell showing disruption of flagellar sheath. FIG. 5. Pair of cells; flagella separating. FIG. 6. Pair of cells showing protoplasmic bridge between copulants. FIG. 7. Pair of cells; flagella completely free.

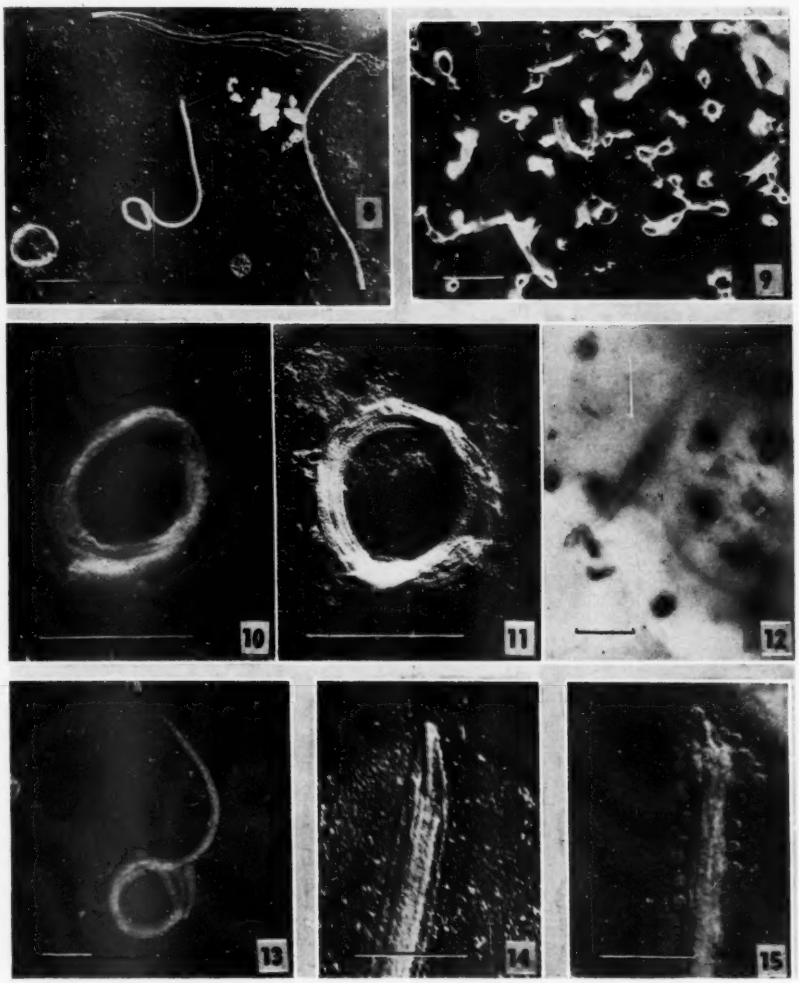
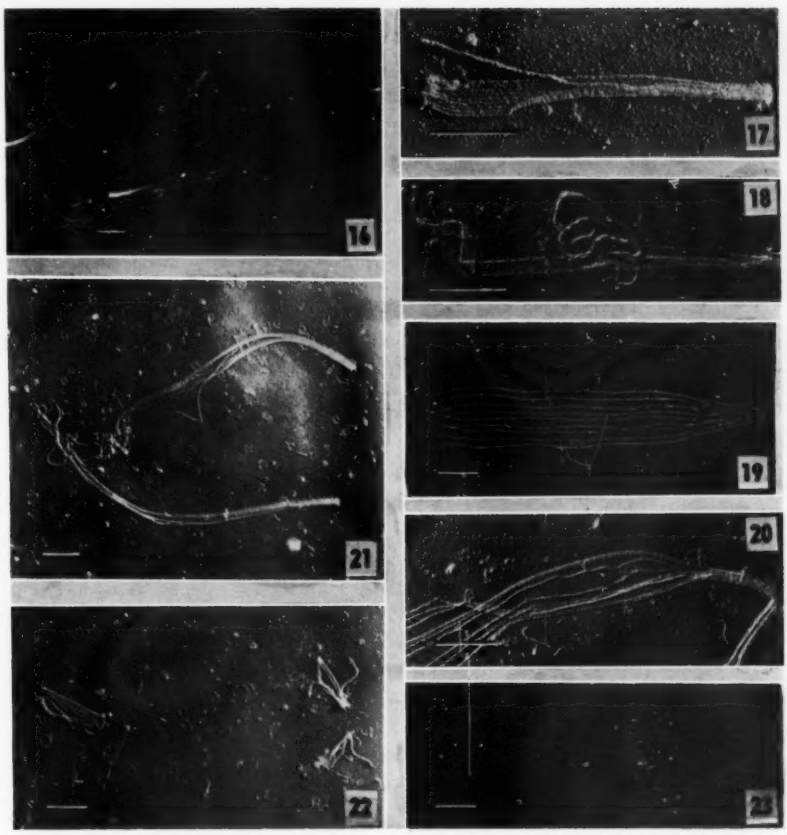


FIG. 8. Detached flagella, showing stages of coiling and fraying. FIG. 9. Sections of flagella. (Plastic used for embedding has been eluted before shadowing.) FIG. 10. Coiled flagellum in intact matrical sac. FIG. 11. Coiled flagellum; matrical sac disrupted. FIG. 12. Sections of flagella. (Embedding plastic not removed.) FIG. 13. Partially coiled flagellum. FIG. 14. Tip of flagellum, with intact membrane. FIG. 15. Tip of flagellum, with globules of matrix.



FIGS. 16–21. Detached flagella, showing separation of fibrils. FIGS. 20–21. Detached flagella, showing transverse banding. FIG. 22. Fragments of disintegrating flagella. Fig. 23. Detached flagellum showing spiral arrangements of fibrils, not usually observed.

cylinder (Figs. 9, 12), though the preparations have not been sufficiently good for differentiation of the individual fibrils, as have those of Watson (39) in sections of sperm tails.

The fibrils are disorganized by treatment with ammonia. They lose their dense, uniform construction, and become tenuous and considerably elongated, as if some material which held the structure in a condensed state had been dissolved by the treatment. The flagella appear to be completely digested by pepsin (pH 2.0), suggesting their protein nature (cf. Astbury and Saha (2)).

Under conditions as yet undetermined, the axial cylinder may break transversely, and fragments of various lengths are of frequent occurrence in preparations of detached flagella (Fig. 22).

(*d*) *The Flagellar Tip*

There are numerous reports in the literature of the presence of a "whiplash", a fine process terminating the main portion of the flagellum, and this has been considered to be a feature of general occurrence in the Volvocales (32). As a rule, such reports have been based on observation of dried mounts prepared in a manner customary among bacteriologists, by which the flagella are first mordanted and then stained by some basic dye. The flagella of *C. moewusii* (like those of *C. dysosmos*, the only other species examined in the course of these studies) were found to end in a short mucro (Fig. 14), and to be devoid of any sign of an attenuated whiplash. It is claimed by Gerloff (14) that a whiplash is present in *C. moewusii*; but it seems very unlikely that fixation by alcohol or osmium tetroxide could cause it to disappear without trace in electron micrograph mounts, and the possibility has therefore to be considered that records of whiplashes are, at least in some cases, based on artefacts. On the other hand, there is no doubt that in some organisms a well-defined whiplash can be demonstrated, as for instance in *Olpidium* (30, 31). It may well be that in other species of *Chlamydomonas* a whiplash actually does exist, representing, as it were, an elongation of the mucronate tip observed in *C. moewusii*. This remains to be demonstrated.

Discussion

Mechanics of Action of Flagella

The normal action of the flagella consists of an alternation of a forceful backward beat with a return stroke, and is associated with a sinistral rotation of the organism about the cell axis. Detached flagella have never been observed to exhibit autonomous activity. However, in microscopic observation of individual living cells, partially immobilized against the slide or cover glass, it can be seen that the tip of the flagellum may move actively while a region more proximal to it remains motionless, providing evidence that the flagellum under normal swimming conditions is not merely moved passively through the water like a whip. Flagellar movement might result from a metachronal rhythm of tensions in the 10 flagellar fibrils constituting the axial cylinder. If so, the fibrils could conceivably be subjected to a rhythmic

series of tugs originating within the cell below the flagellar attachment, or, more probably, they might contract and extend in association with chemical energy changes taking place within the flagellum itself. However, one should also envisage the possibility that contractile protein, which presumably constitutes some portion of the flagellum, may exist in the less dense matrical material of the flagellar sheath (33) or even in the more fluid contents of the axial cylinder, and that the fibrils constitute merely a cylinder of resilient struts against which the alternating tensions can act. Further experimentation is certainly needed on this point.

A number of paralyzed strains of *Chlamydomonas* have been obtained as mutants following irradiation of wild-type cells by ultraviolet light (24). In these mutants the cells, although furnished with flagella of normal length, are apparently incapable of swimming. The flagella of eight of these mutant types have been examined under the electron microscope, but in no case has it been possible to detect any structural differences from the wild type.

Acknowledgments

The authors are indebted to Dr. W. H. Gaylord for much valuable advice and technical assistance, and to Dr. J. L. Melnick, Dr. W. G. Banfield, and Dr. H. Bunting who kindly made available for these studies the electron microscope and the adapted microtome.

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A SLIDE TECHNIQUE FOR THE STUDY OF FUNGI AND ACTINOMYCETES IN SOIL WITH SPECIAL REFERENCE TO *HELMINTHOSPORIUM SATIVUM*[1]

By S. H. F. Chinn[2]

Abstract

A slide technique suitable for studying the behavior of fungi and actinomycetes both qualitatively and quantitatively in soil is described. Besides *Helminthosporium sativum*, eight other fungi and one actinomycete were used to demonstrate the applicability of the method which was used for both natural and soybean meal amended soils. In the natural soil spores of *Penicillium notatum*, *Stachybotrys atra*, and the actinomycete only germinated. However, lysis or disintegration of the germ tubes of the two fungi was observed on the fourth day. Growth of the actinomycete was continuous to at least the seventh day. In the amended soil only one fungus failed to germinate. Of those that germinated, only *Fusarium culmorum* and the actinomycete were capable of continued growth and sporulation. Lysis or disintegration of the germ tubes of the others was noticed on the fourth day.

Introduction

A number of methods have been employed for the direct examination of microorganisms in soil. Blair (2) adequately reviewed the work of a number of authors who have developed methods for the study of the microflora of the soil. He also mentioned a number of investigations of soil-borne diseases in which the most recently developed technique, the Rossi-Cholodny slide method, was used. Essentially, this technique consists of burying microscope slides in soil for a specified period and then removing, fixing, and staining the slides for examination. This technique was applied by Blair (1) in a study of the behavior of *Rhizoctonia solani* in soil. He showed that the fungus grew as a saprophyte in natural, unsterilized soil and that the growth rate of the fungus was influenced by soil conditions.

In order to substantiate an hypothesis on the mechanism of common rootrot control, it was necessary to understand how the pathogen, *Helminthosporium sativum*, behaves in soil. Preliminary studies with the Rossi-Cholodny technique suggested that this procedure was not applicable to the study of this fungus. The present paper describes a slide technique which is suitable for observing the growth behavior of *H. sativum* in soil. Both qualitative and quantitative effects can be demonstrated. It was found to be applicable to the study of other fungi and actinomycetes.

Materials and Methods

Besides *H. sativum*, eight other fungi, mostly obtained from the Departments of Agricultural Bacteriology and Biology, University of Saskatchewan, and one actinomycete recently isolated from soil were used in the study.

[1] *Manuscript received June 24, 1953.*

Contribution No. 359 from Bacteriology Division, Science Service, Department of Agriculture, Ottawa.

[2] *Associate Bacteriologist, Laboratory of Plant Pathology, Science Service, Saskatoon, Sask.*

PLATE I

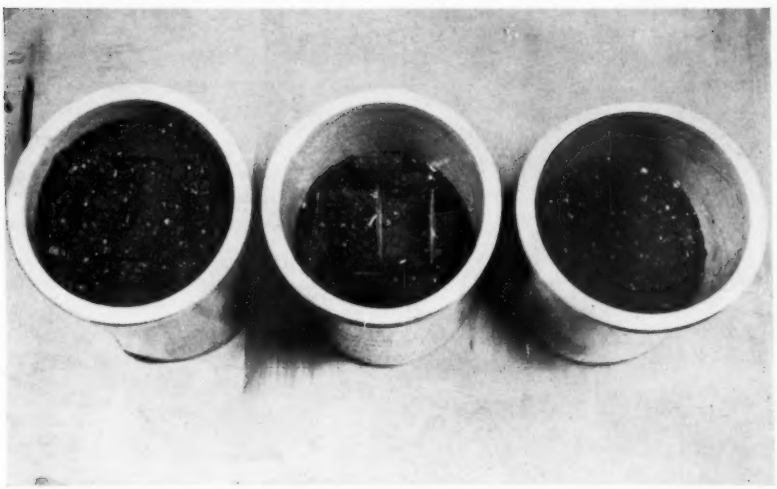

FIG. 1. Arrangement of microscope slides in crocks for growth studies of fungi and actinomycetes in soil. R. to L.: crock about half-filled with soil; inoculated slides inserted about one-quarter inch into the soil; slides covered with soil.

The fungi were grown on potato-dextrose agar slants and the actinomycete on a nutrient agar slant. The cultures were incubated usually for about seven to ten days at room temperature. Then the growth culture was suspended in 10-ml. aliquots of a detergent, "Tween 20" (diluted 1 : 5000). The suspension was passed through a fine copper screen to remove some of the mycelium and the screened material was transferred into a 250-ml. beaker containing approximately 200 ml. of sterile 1% plain agar which had been previously melted and cooled to about 45° C. The contents were mixed and the agar suspension maintained at this temperature in a water bath for further use. All work was done under aseptic conditions.

Soils used in the investigation were sieved and moistened to about 50% moisture holding capacity. Quarter-gallon glazed crocks about half-filled with soil were used.

Ordinary microscope slides, thoroughly cleaned and sterilized, were dipped momentarily, one at a time, into the agar suspension of spores, removed, and inserted vertically about one-quarter of an inch into the soil as illustrated in Fig. 1. Several slides can be used depending on the number of examinations required. After the agar had solidified, additional soil was used to cover the slides. In order to conserve moisture large Petri plate lids were used as covers for the crocks. Water was added to the soil when necessary. Incubation was at room temperature.

At the end of each specified period a slide was lifted from the soil in such a manner as to cause the least disturbance to the growth of the fungus and to the remaining slides in the soil. This was accomplished by removing a small amount of soil adjacent to one side of the slide with a spatula. Then the slide was pressed towards the opening and lifted out. The opening caused by the removal was filled and the crock again incubated until the next examination. After removal, the slide was rinsed with water to remove most of the soil adhering to the film of agar. The agar on one side of the slide was removed with a spatula, the slide rinsed in water and stained by immersion in a dilute solution of cotton blue in lactophenol for 10 min.

Examination was made immediately, usually with the low power objective and occasionally with the high dry objective. When the surface of the agar film became dry the addition of a drop of the cotton blue solution facilitated observation. Slides were removed at 16 and 40 hr., and 4, 7, and 14 days. Those removed after the first and second intervals were examined for germination of the conidia or spores. Percentage germination was calculated on a basis of examinations of 50 conidia taken at random, the approximate average length of the germ tubes being recorded. Slides removed at later intervals were examined for signs of further development of the germ tubes or of lysis or disintegration of the germ tubes and hyphae. In some tests an estimate only was made of the percentage germination at 16 hr. Disintegration of germ tubes and hyphae was noted only at four and seven days, except in one instance when the 14-day examination was made.

Two sets of experiments were performed to demonstrate the applicability of the slide technique. In one set where only *H. sativum* was studied, clay loam and sandy loam soils were used. The soils were either nontreated, sterilized, or amended with 2% soybean meal. In the second set where all nine fungi and the actinomycete were studied, a loamy soil either nontreated or amended with 2% soybean meal was used.

Results and Discussion

The results as presented in Table I illustrate the behavior of *H. sativum* under three soil conditions. In the natural untreated soil the fungus remained in a dormant condition (Fig. 2) which is in accordance with the findings of Simmonds (3) who pointed out the tendency of most soils to prevent germination of the conidia of *H. sativum*. As expected, in the sterilized soil, germination was exceedingly high if not complete. Growth was quite extensive for the first few days. Further development was very limited and sporulation was observed rarely even after 14 days, indicating that the environment of the soil was satisfactory for germination of the conidia though not generally suitable for further growth of the fungus.

Germination was quite extensive at 16 hr. (Fig. 3) in the amended soil and the germ tubes continued to develop for a short period but by, or before, the fourth day further growth was not observed; in fact beginning of lysis or disintegration of the germ tubes and hyphae was quite noticeable at that date and lysis was well advanced in seven days as illustrated in Fig. 4.

The destruction of *H. sativum* may then be assumed to be due to two actions. Germination of the conidia is believed to be caused by a stimulant in the soybean meal after which the fungus is destroyed, presumably by the action of toxic products which may be present prior to amendment or are formed as a result of the activities of the microflora of the soil on the organic addenda.

Table I also shows that there was no significant increase in percentage germination between the 40 hr. and the 16 hr. examination. Evidence obtained in other tests which will be reported later suggested that only that portion of the germinating factor in contact with the conidia was used by them for germination. The rest probably was metabolized rapidly by the soil microflora or reacted with substances of the soil and became unavailable to the fungus. In the examination it was observed that the germination of the conidia was quite uniform throughout the slide.

The results obtained with the clay loam soil showed no significant differences from those with the sandy loam soil; therefore, the data on the clay loam soil are not reported.

The data in Table II demonstrate that fungi, some of which are considered to be very prolific soil-inhabiting types, developed rather slowly, if at all, in natural soil. Of the nine fungi and one actinomycete, spores of only three, namely *Penicillium notatum* (Fig. 5), *Stachybotrys atra*, and the actinomycete germinated in natural soil. The percentage germination of the two fungi was very low at 16 hr. though some additional germination was noted at the fourth and seventh day. No elongation of the germ tubes into mycelial

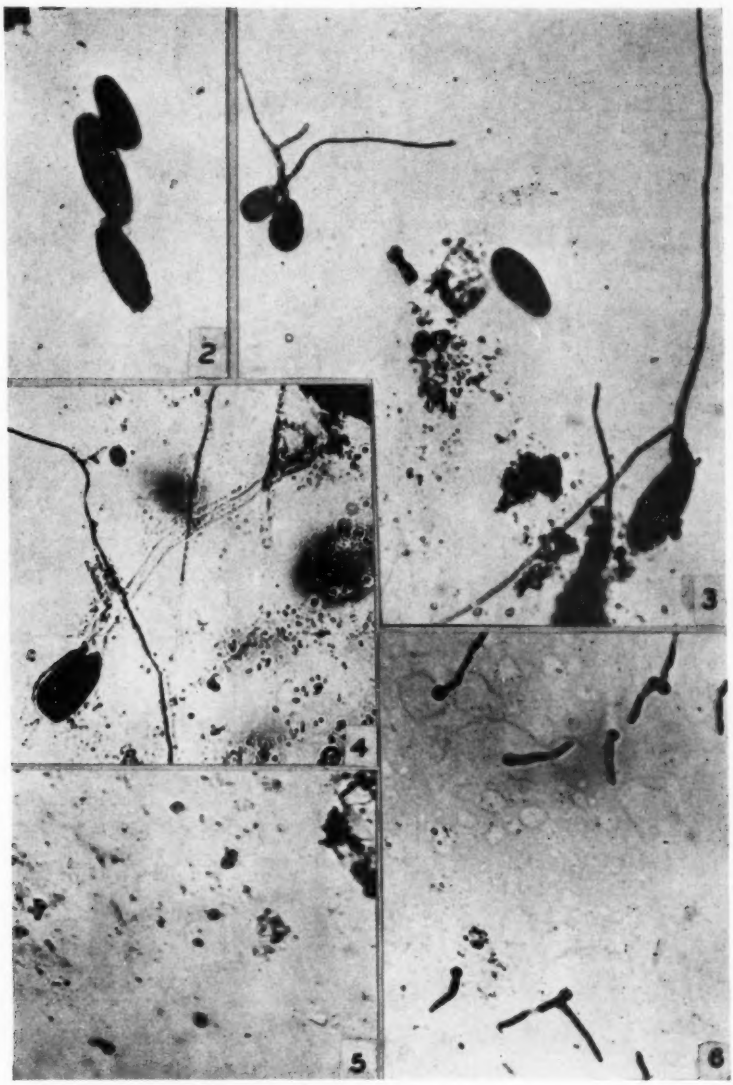

FIG. 2. Conidia of *H. sativum* in natural soil 16 hr. × 312. Conidia not germinating. FIG. 3. Conidia of *H. sativum* in 2% soybean meal amended soil 16 hr. × 312. Note germination except with one conidium. FIG. 4. As in Fig. 3, except examination was made at end of one week. × 430. Lysis of germ tube is well advanced. FIG. 5. Spores of *P. notatum* in natural soil 16 hr. × 312. Note germination and short germ tube of one spore. FIG. 6. Spores of *P. notatum* in 2% soybean meal amended soil 16 hr. × 430. Note complete germination and extensive development of germ tubes.

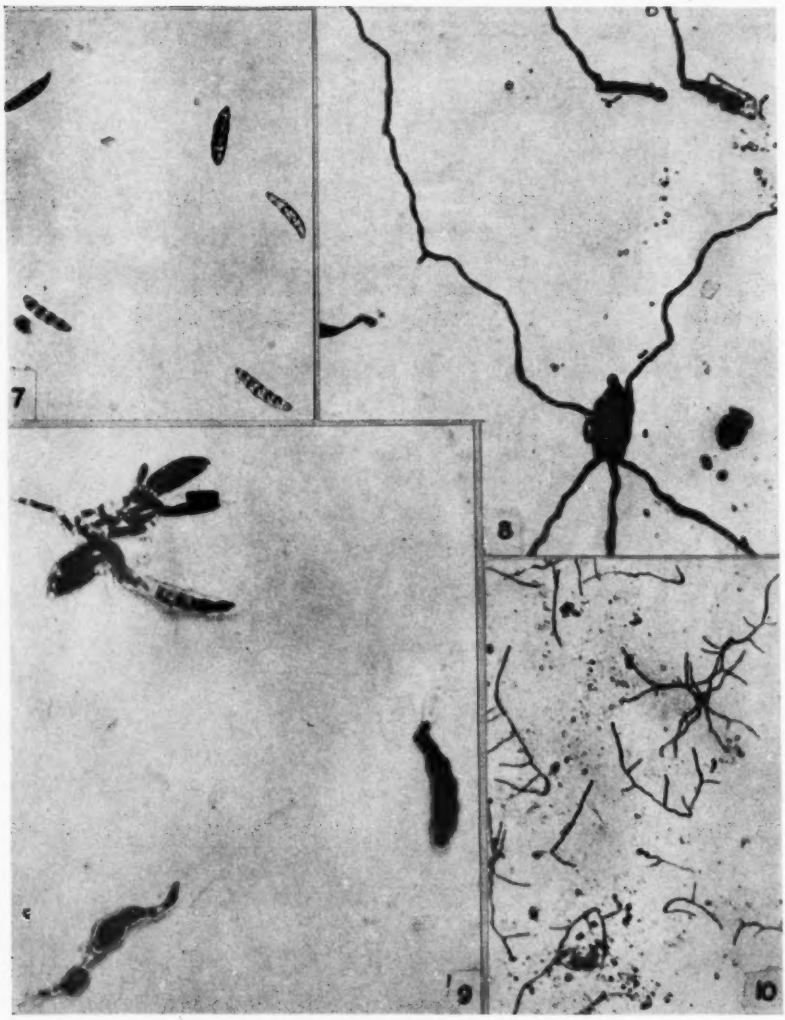

FIG. 7. Conidia of *F. culmorum* in natural soil 16 hr. × 312. No germination occurred. FIG. 8. Conidia of *F. culmorum* in 2% soybean meal amended soil 16 hr. × 312. Note complete germination and extensive development of germ tubes. FIG. 9. As in Fig. 8, except examination was made at end of one week. × 312. Formation of chlamydospores and new conidia were noted. FIG. 10. Spores of actinomycetes in 2% soybean meal amended soil 16 hr. × 430. High germination and extensive hyphal growth.

TABLE I

EFFECT OF SOIL TREATMENT ON THE GERMINATION, GROWTH, AND LYSIS OF *H. sativum* IN SANDY LOAM SOIL

Treatment	Time						
	16 hr.		40 hr.		4 days	7 days	14 days
	% Germination	Approx. length of germ tubes in microns	% Germination	Approx. length of germ tubes in microns			
Natural soil	0	—	0	—	Nil	Nil	Nil
Sterilized soil	75-80	500	95	> 1000	Some increase in growth as compared to 40 hr.	Possibly slight increase in growth as compared to 4 days	Conidia were formed but in exceedingly low numbers
Natural soil plus 2% soybean meal	64	200-500	60	> 1000	Very little if any increase in hyphal development as compared to 40 hr. Lysis noted on some germ tubes and hyphae	Lysis noted on all germ tubes, outlines of wall membrane still prominent (Fig. 4) in most instances	Outlines of wall membrane still noticeable in some instances, in others only the husks of what were formerly conidia remained

TABLE II

EFFECT OF 2% SOYBEAN MEAL ON THE GERMINATION, GROWTH, AND LYSIS OF NINE FUNGI AND ONE ACTINOMYCETE IN SOIL

Species	Amendment	Time			
		16 hr.		4 days	7 days
		% Germination*	Approx. length of germ tubes in microns		
Helminthosporium sativum	Natural soil	0	—	No change	No change
	Amended soil	+++	250-750	Lysis of some germ tubes	Lysis of all germ tubes
Fusarium culmorum	Natural soil	0	—	No change	No change
	Amended soil	++++	350-700	Extensive development of hyphae	Lysis of some hyphae, chlamydospores very common, and a few new conidia seen
Penicillium notatum	Natural soil	+	50 or less	Additional germination (++), all germ tubes very short	Possibly no change in germination as compared to 4 days, germ tubes not increasing in length, some indications of lysis
	Amended soil	++++	125-250	Slight increase in length of germ tubes	Lysis of all germ tubes
Cladosporium sp.	Natural soil	0	—	No change	No change
	Amended soil	+	50	Slight increase in length of germ tubes	Complete lysis of all germ tubes
Tricoderma sp.	Natural soil	0	—	No change	No change
	Amended soil	++	125	No noticeable change	Nearly complete lysis of all germ tubes
Stachybotrys atra	Natural soil	+	100	Additional germination (++), slight increase in length of germ tubes	Lysis of germ tubes
	Amended soil	++++	125	Some increase in length of germ tubes, possibly lysis has set in	Lysis well advanced

TABLE II—*Concluded*

EFFECT OF 2% SOYBEAN MEAL ON THE GERMINATION, GROWTH, AND LYSIS OF NINE FUNGI AND ONE ACTINOMYCETE IN SOIL

Species	Amendment	Time			
		16 hr.		4 days	7 days
		% Germination*	Approx. length of germ tubes in microns		
Aspergillus sp.	Natural soil	0	—	No change	No change
	Amended soil	++++	100	Lysis of germ tubes well advanced	Complete lysis of germ tubes
Ustilago nuda	Natural soil	0	—	No change	No change
	Amended soil	0	—	No change	No change
Ustilago hordei	Natural soil	0	—	Slight germination (+), lysis also seen	Complete lysis of all germ tubes
	Amended soil	++++	100	Lysis of germ tubes	Complete lysis of all germ tubes
Actinomycete	Natural soil	+	25	Germination (++), growth of hyphae very sparse	Germination (+++), growth of hyphae very sparse
	Amended soil	++++	35	Extensive branching and development of hyphae	Continued extensive branching and development of hyphae

NOTE: *Examination of the actinomycete in amended soil was also made at 14 days and fragmentation of the hyphae into oidiospores was noted.*

* *Approximately* 90 – 100% germination = ++++
" 50 – 89% " = +++
" 10 – 49% " = ++
" 1 – 9% " = +.

growth was observed with *P. notatum* at any of the three intervals. Slight lengthening of the germ tubes was noted with *S. atra* at the fourth day. Lysis began in both fungi about the seventh day indicating the presence of mycolytic substances in the natural soil. Limited germination of actinomycetes was seen at 16 hr. but percentage germination was progressively higher at the later intervals. Some mycelial development was observed with no indication of disintegration of the mycelium. An illustration of dormant conidia of *F. culmorum* is shown in Fig. 7.

Of the three organisms only the actinomycete showed a tendency to develop in natural soil, implying that of all the cultures studied, this was the only true soil inhabitant.

Table II also shows that when the soil was amended with 2% soybean meal, percentage germination was high in seven instances, fair in one, low in one, and nil in one. Illustrations of spores of *P. notatum* and conidia of *F. culmorum* germinating in the amended soil are shown in Figs. 6 and 8, respectively. Another observation was that although instances of germination were high only two cultures, namely, *F. culmorum* and the actinomycete, were able to continue growth after about the fourth day. Unfavorable soil factors prevented the others from further development and caused the disintegration of their germ tubes and hyphal growth. Of the two cultures which continued to develop, a few new conidia and clamydospores were seen on the *F. culmorum* slide as illustrated in Fig. 9. Results of this study suggest that *F. culmorum*, commonly thought of as a soil inhabitant, should not be considered so in the strict sense. Germination and reproduction depend on certain foodstuffs, such as those provided by soybean meal, in the soil, since the inert organic matter present in the natural soil is not sufficient for the development of the fungus. However, its ability to continue growth after germination in the amended soil places it in a different class from the other fungi which germinated but were unable to complete their cycles of growth.

High germination and good mycelial development of the actinomycete was noted at 16 hr. as illustrated in Fig. 10. Mycelial development was progressive at the fourth and seventh days and fragmentation of the hyphae and oidial formation were observed on the 14th day.

Acknowledgments

The writer wishes to express his appreciation to Mr. R. J. Ledingham and Drs. P. M. Simmonds and B. J. Sallans for assistance and many valuable suggestions and criticisms during the course of this investigation.

The writer is also indebted to Dr. A. G. Lochhead for his helpful advice and the final reading of this manuscript.

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BACTERIOPHAGE IN RELATION TO *XANTHOMONAS TRANSLUCENS*[1]

By H. Katznelson and M. D. Sutton

Abstract

A phage specific for one isolate of *Xanthomonas translucens* f. sp. *undulosa* and three polyvirulent phages active against various members of the *X. translucens* group have been isolated. One of the polyvirulent phages, Pg35, lysed 24 out of 28 isolates of *X. translucens*; the other two were somewhat less active. Attempts to use form specific phages to identify cultures of *X. translucens* f. spp. *hordei*, *hordei-avenae*, and *undulosa* were unsuccessful. However, use of a phage specific for f. sp. *secalis* to detect homologous cultures gave encouraging results.

Introduction

In a previous publication Sutton and Katznelson (5) reported the isolation of phages specific for *Xanthomonas translucens* formae speciales *hordei*, *hordei-avenae*, and *secalis* from cereal seed and suggested their possible use in identifying these variants. Such a procedure would be much simpler and less time consuming than plant inoculation or serological techniques both of which have been used to identify members of the *X. translucens* group (1, 2, 3). Further efforts have been made during the past year to isolate other phages especially for the f. spp. *undulosa*, *cerealis*, and *phleipratensis*. Partial success was achieved, and in addition, several phages were isolated which attacked many forms and one which attacked practically all of the *X. translucens* isolates in our collection. Consequently, additional named cultures were obtained from various sources for more extensive tests, the results of which are reported below.

Methods

The new phages were obtained by grinding cereal seed with sand and mixing the seed with composted soil, raw sewage, nutrient broth, and calcium carbonate to give a loose mud and inoculating the mixture heavily with a suspension of the strains for which a phage was desired. After 24–48 hr. at room temperature the mixture was passed through filter paper, the filtrate centrifuged, and the supernatant liquid passed through sterile, ultrafine, sintered glass filters; 1–2 ml. portions of the sterile filtrate were added to 10 ml. sterile, nutrient broth in 50-ml. Erlenmeyer flasks and the mixture inoculated with the homologous organism. After 24 hr. the suspension was centrifuged, filtered, and the filtrate retested. Usually two to three such serial passages were sufficient to demonstrate the presence of an active phage. If distinct or complete clearing was not observed at this time, it was not possible to demonstrate the presence of a phage even after six passages.

[1] *Manuscript received July 10, 1953.*

Joint contribution from the Divisions of Bacteriology and Dairy Research (Contribution No. 362) and Botany and Plant Pathology (Contribution No. 1294), Science Service, Department of Agriculture, Ottawa, Canada.

Concurrently, samples of the original sterile filtrates were also added to Petri plates containing a heavy suspension of the organism concerned and the mixture plated with yeast-beef agar (Difco). Plaques were frequently observable within 6–12 hr. if an active phage was present.

The phages isolated were plated to produce plaques, which were picked into broth cultures; the resulting cleared cultures were filtered and used to build up stocks of pure-line phages.

Each new phage was tested against all the *Xanthomonas* species which had been collected, as well as on all the *X. translucens* cultures.

Results

Four phages were isolated by the method described. None showed activity against the isolates of *Xanthomonas* spp. other than those of *X. translucens* listed elsewhere (4) or newly acquired. Their action on the form species of *X. translucens* in the stock collection is indicated in Table I. Phage MPg34 is specific for f. sp. *undulosa*. The three remaining phages were not so specific; they lysed all but one of the test organisms; Pg35 lysed a representive of every form species, whereas KPg34 and KPg37 did not attack f. sp. *hordei-avenae*. These three phages did not attack *X. begoniae*, *X. cucurbitae*, *X. juglandis*, *X. carotae*, *X. maculafoliumgardeniae*, species which have been included in the *X. translucens* group on the basis of their immunological reactions by Elrod and Braun (1).

TABLE I

LYSIS OF MEMBERS OF THE *Xanthomonas translucens* GROUP BY FOUR NEWLY ISOLATED PHAGES*

Culture No.	*X. translucens* f. spp.	Phage			
		MPg34	KPg34	KPg37	Pg35
P36	*hordei*	0	4	4	3
P38	*secalis*	0	4	4	3
P50	*hordei-avenae*	0	0	0	4
P34	*undulosa*	4	4	4	3
P37	*cerealis*	0	4	4	4
P25	*cerealis*	0	4	4	0
P35	*phleipratensis*	0	4	4	4

* *Numbers 0 to 4 represent increasing degree of lysis from none (0) to complete (4).*

Additional data on phage lysis of various cultures of *X. translucens* obtained from several different sources are given in Table II. It may be seen that all but three are lysed by phage Pg35 and that of these, one (P71) is lysed by phage KPg34; the other two were resistant to all the phages. There was no apparent uniformity in the susceptibility of the cultures to KPg34 which lysed less than 50% of these. The phage which was specific for f. sp. *undulosa* (P34 Table I) did not attack any of the new cultures labeled *undulosa*, but did lyse the unlabeled P75 culture which suggests a very close relationship between these two isolates. Two cultures thought to be f. sp. *hordei*, and one

TABLE II

SUSCEPTIBILITY OF VARIOUS ISOLATES OF *X. translucens* TO PHAGES*

Accession Number of isolate	Form species of *X. translucens*	Source	Degree of lysis obtained by phages					
			MPg34 (*undulosa*)	Pg36 (*hordei*)	Pg38 (*secalis*)	Pg50 (*hordei-avenae*)	KPg34 (general)	Pg35 (general)
P63	*hordei-avenae*	Hagborg 24	0	0	0	4	0	4
P64	" "	" 21	0	0	0	0	0	0
P65	*undulosa*	" 22	0	0	0	0	0	4
P66	"	" 17	0	0	0	0	4	4
P67	*cerealis*	" 3	0	0	0	0	4	4
P68	*secalis*	" 11	0	0	4	0	4	4
P69	"	" 15	0	0	4	0	4	3
P101	*cerealis*	" 23	0	0	0	0	4	4
P83	*hordei*?	Boosalis Bt-1	0	0	0	0	0	3
P82	" ?	" Bc-1	0	0	0	0	0	4
P80	*cerealis* (*undulosa*?)	" B-22	0	0	0	0	0	0
P81	*hordei*	" Ba-10	0	0	0	0	0	3
P79	*cerealis*	" Q-1	0	0	0	0	0	4
P77	*undulosa*	" W-6	0	0	0	0	0	2
P78	"	" W-9	0	0	0	0	4	2
P84	?	Dowson 715	0	0	0	0	4	4
P71	*cerealis*?	Starr XT-12	0	0	4	0	4	0
P72	*cerealis*	" XT-13	0	0	0	0	0	2
P74	*undulosa* or *cerealis*	" XT-15	0	0	0	0	0	3
P75	?	" XT-18	3	0	0	0	4	4
P76	*phleipratensis*	" XT-102	0	0	0	0	0	4

* *See Table I.*

identified as such, did not respond to the f. sp. *hordei* phage whereas one of the two f. sp. *hordei-avenae* cultures was susceptible to the corresponding phage. The other isolate (P64), along with culture P80, was not sensitive to any of the phages used and they may not be *X. translucens*. Two cultures submitted as f. sp. *secalis* and one (P71), the identity of which was questioned, were found to be susceptible to the f. sp. *secalis* phage.

Discussion

The data presented show that of 28 cultures thought to be variants of *X. translucens*, 24 were lysed by phage Pg35 and of the 4 remaining, 2 were lysed by phage KPg34. Thus, 91% of the cultures tested could be assigned to the species *X. translucens* on the basis of phage lysis. The remaining two cultures were refractory to all the phages and raised the question as to whether they are members of this group at all.

The relationship between the form species of *X. translucens* and certain other species of this genus (*X. begoniae*, *X. cucurbitae*, etc.) as brought out in the immunological work of Elrod and Braun (1) is not supported by the phage-susceptibility studies. However it is possible that the cultures tested, though resistant to phage, may still be serologically related to the susceptible cultures. This is not to say that serological methods *per se* offer the most reliable criteria. For example, Elrod and Braun (1) placed isolates of f. spp. *hordei*, *undulosa*, and *cerealis* in one group, which they call the "cerealis group", on the basis of their serological identity, yet Fang *et al.* (2) in similar studies separated these form species into distinct serological types: (*a*) *hordei*, (*b*) *undulosa-secalis*, (*c*) *cerealis*, and included a fourth (*d*) *phleipratensis* which was not available to Elrod and Braun (1).

X. translucens f. sp. *hordei-avenae* of Hagborg (3) is not considered a valid form species by Fang *et al.* (2) who include it with f. sp. *hordei* on the basis of pathogenicity. Yet its resistance to phages KPg34 and KPg37 which lyse all the other form species as well as f. sp. *hordei* would suggest that it differs from these. Furthermore there was no crossing over in susceptibility of f. sp. *hordei* to phage for f. sp. *hordei-avenae* or vice versa (5).

It would seem that the available phages, with the possible exception of that for f. sp. *secalis*, are, in general, too specific for use in identifying the corresponding form species, because they appear to be strain-specific in their reactions. A number of attempts have been made to isolate specific phages for f. sp. *cerealis* and *phleipratensis*. However the resulting phages were polyvirulent (KPg34 or KPg37 and Pg35) as compared with the specificity of the phages for f. spp. *hordei*, *hordei-avenae*, *secalis*, and *undulosa*. Further efforts are being made therefore to obtain form-species-specific phages.

Acknowledgment

The authors wish to thank Drs. M. P. Starr, M. G. Boosalis, W. A. F. Hagborg, A. J. Riker, and W. J. Dowson for supplying cultures used in this study.

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PHYSIOLOGICAL VARIATIONS AND HOST PLANT SPECIFICITIES OF RHIZOBIA ISOLATED FROM *CARAGANA ARBORESCENS* L.[1]

By K. F. Gregory[2] and O. N. Allen[3]

Abstract

The physiological characteristics and host plant relationships of 14 strains of rhizobia, isolated from the nodules of *Caragana arborescens* L., have been studied. The nodules from which these isolates were obtained came from six widely separated localities in North America. The strains differed markedly in rates of growth, in their ability to reduce nitrate, in their reactions in litmus milk and on 12 carbohydrate media, and in their abilities to fix nitrogen symbiotically. The strains showed uniformity in their abilities to produce nodules on *Phaseolus vulgaris, Colutea arborescens, Lespedeza stipulacea, Trifolium pratense,* and *Lotus corniculatus.* Because these species are now included in separate bacterial–plant groups, an assignment of *C. arborescens* to a cross-inoculation group appears unwise at this time. Thirty strains of rhizobia isolated from 20 species contained in 15 leguminous genera failed to nodulate *C. arborescens* in greenhouse tests. Various examples of nonreciprocal cross-inoculation were noted. Strains of caragana rhizobia reisolated from nodules formed by them on *Trifolium pratense* and *Colutea arborescens* retained their abilities to form nodules on *Caragana arborescens.*

Introduction

Caragana arborescens L., indigenous to Siberia and Manchuria, is an erect shrub or small tree commonly known in North America as caragana or the Siberian pea tree. In cool, semiarid regions, it is widely used as an ornamental shrub and windbreak (13). On the basis of data obtained by Maassen and Muller in 1907, Fred, Baldwin, and McCoy (6) listed *C. frutescens* DC. (trailing wild bean), a species closely related to *C. arborescens*, in a cross-inoculation group separate and distinct from all other bacterial–plant groups. In 1939, Wilson (10) found that strains of rhizobia from the nodules of *C. frutescens* produced nodules on diverse leguminous species. The taxonomic status of rhizobia from nodules of this plant is confused further by many examples of nonreciprocal cross-inoculation (12).

The present work was undertaken to determine some of the physiological characteristics and cross-inoculation specificities of rhizobia isolated from *C. arborescens* L.

Methods

Fourteen strains of rhizobia isolated from plants of *C. arborescens* growing in widely separated localities in North America were employed (Table I). Five of these strains were obtained from the collection of the Department of Bacteriology, University of Wisconsin. Three strains were kindly made available by Dr. J. C. Burton from the collection of The Nitragin Company,

[1] *Manuscript received July 10, 1953.*
Contribution from the Department of Bacteriology, University of Wisconsin, Madison 6, Wisconsin. Published with the approval of the Director of the Wisconsin Agricultural Experiment Station.

[2] *Research Assistant. Present address: Assistant Professor, Department of Bacteriology, Dalhousie University, Halifax, Nova Scotia.*
[3] *Professor of Bacteriology.*

Milwaukee, Wis. Six strains were isolated from nodules on plants growing at the Agassiz Experimental Farm, Agassiz, B.C., and the Beaverlodge Experimental Station, Alta. Ten other strains of rhizobia from the local collection, namely: *Rhizobium meliloti* 107, *R. trifolii* 202 and 205, *R. phaseoli* 403 and 412, cowpea strain 611, peanut strain 625, *Agrobacterium radiobacter* 1000 and 1006, and *A. tumefaciens* 1011 were used for comparative purposes in the cultural tests. Thirty additional strains of rhizobia isolated from 20 species contained in 15 leguminous genera were employed in the plant inoculation tests (Table III).

The ability of the rhizobia from caragana to reduce nitrate was determined in Riker, Lyneis, and Locke's medium (7) which was modified by the substitution of glucose for sucrose and the addition of 8 ml. of yeast water per liter. The presence of ammonia, nitrite, and nitrate were determined according to the techniques prescribed in the Manual of Methods of the Society of American Bacteriologists (8).

Acid production by species of the genera *Rhizobium* and *Agrobacterium* was determined in 12 carbohydrate media (Table I). A modification of Baldwin and Fred's weakly buffered basal medium (3) was employed. Since preliminary experiments showed that certain strains which caused the production of acidity followed by alkalinity in Baldwin and Fred's medium also reduced nitrate to ammonia, it was reasoned that the rise in pH was due to ammonia production resulting from nitrate reduction. Substitution of ammonium sulphate for sodium nitrate avoided this reversal of reaction.

Bromothymol blue was added to all the media and the initial reactions were adjusted to pH 7.0. All the carbohydrates were sterilized separately by Seitz filtration and added aseptically to the basal medium. Agar slants of the various media were streaked with 72-hr. broth cultures of the organisms. Extent of growth and changes in reaction were noted throughout a two weeks' incubation at room temperature.

The plant inoculation tests were conducted under carefully controlled greenhouse conditions. The seeds of the test plants were surface-sterilized for one hour with a solution of calcium hypochlorite containing 2% available chlorine and germinated on yeast-water mannitol agar (2). Only those seedlings free of contamination were employed. In most tests the plants were grown in cotton-plugged glass jars containing sterile, white quartz sand. Ten to twelve plants were grown in each jar. Duplicate jars of each plant species were inoculated with each culture tested. Bond's modification of Crone's nitrogen-free nutrient solution was added when necessary (1). The plants in the greenhouse were maintained for at least two weeks after nodules were well-developed on those plants which had been inoculated with the compatible strains of rhizobia.

The efficiency of symbiotic nitrogen fixation by the caragana rhizobia on their parent host species was determined by growing the test plants in a mixture of two parts of white quartz sand to one part of vermiculite contained in glazed pots prepared according to the method of Erdman and Burton (5).

Total nitrogen was determined by the semimicro-Kjeldahl procedure of Umbreit and Bond (9) with Hengar granules substituted for $CuSeO_3$. The digested mixture was diluted, an aliquot Nesslerized, and the amount of nitrogen determined colorimetrically in an Evelyn colorimeter.

Results

Cultural Tests

Although all the strains of rhizobia from *C. arborescens* belonged to the so-called slow-growing group of rhizobia, marked variations in rates of growth by the isolates were noted. Colonies of strains 725 to 729 inclusive, were first visible on yeast-water mannitol agar plates after six days' incubation at 23° C., however, they did not reach their maximum size (diam. up to 1.0 cm.) for almost two weeks. Colonies of strains 1030 to 1038, inclusive, required eight days to become visible and about three weeks to attain the same maximum size as the former strains.

Rhizobia have been divided commonly into four categories relative to their action on litmus milk, i.e., alkaline, with and without serum zones, and acid, with and without serum zones (6). All these reactions were encountered among the strains of caragana rhizobia (Table I). Strains 725 to 729, inclusive, showed the most rapid growth on agar slants of yeast-water mannitol agar and produced during the first six weeks' incubation, the deepest serum zones in litmus milk of all the strains. These zones comprised 60% of the total volume of the milk in the tubes. Four strains, namely 1030, 1031, 1034, and 1035, produced alkaline reactions with relatively small serum zones.

TABLE I

PHYSIOLOGICAL CHARACTERISTICS OF RHIZOBIA ISOLATED FROM *Caragana arborescens* L.

Strain No.	Source	Date of isolation	Litmus milk		Carbohydrates allowing acid production*	Nitrate reduction
			Reaction	Serum zone (depth in mm.)		
725	Wisconsin	1946	Alkaline	24	1,3,5,11,12	+
726		1946	"	24	1,3,5,11,12	+
727		1946	"	24	1,5,11,12	0
728	Collection of L. T. Leonard, U.S.D.A.	1935	"	23	1,5,11,12	+
729	Ohio	1934	"	22	1,5,11,12	+
1030	Agassiz Experimental Farm, Agassiz, B.C.	1947	"	16	1,5,11,12	0
1031		1947	"	13	1,3,5,11,12	0
1032		1947	"	0	1,3,5,11,12	0
1033		1947	Acid	0	1,2,3,4,5,9,11,12	0
1034		1947	Alkaline	15	1,3,11,12	0
1035	Beaver Lodge Experimental Station, Alta.	1947	"	15	1,5,11,12	++
1036	The Nitragin Co., Milwaukee, Wis.	1948	Acid	0	1,2,3,4,5,9,11,12	0
1037		1948	"	3	1,2,3,4,5,9,12	0
1038		1948	"	3	1,2,3,4,5,9	++

* *Carbohydrates tested were (1) arabinose, (2) xylose, (3) glucose, (4) galactose, (5) mannose, (6) fructose, (7) sucrose, (8) maltose, (9) lactose, (10) dextrin, (11) glycerol, and (12) mannitol.*

Strain 1032 brought about an alkaline reaction without a serum zone. Acid reactions without serum zone formation were caused by strains 1033 and 1036. Acid reactions with small serum zones were observed with strains 1037 and 1038.

Eight strains of rhizobia from *C. arborescens* failed to produce nitrite in the nitrate medium after four weeks' incubation (Table I). Tubes of this medium inoculated with strains 1035 and 1038 gave strongly positive tests for nitrite, whereas four cultures, namely: 725, 726, 728, and 729, gave weakly positive tests.

Carbohydrate fermentation tests revealed a great diversity of reactions among the strains of caragana rhizobia (Table I). The diversity of reactions among these strains was as great as that found among the seven strains of rhizobia isolated from alfalfa, red clover, garden bean, cowpea, and peanut (data not included in Table I). All the monosaccharides, namely: arabinose, fructose, galactose, glucose, mannose, and xylose were readily utilized as carbon sources for growth by the rhizobia cultures tested. Most strains produced acid from all these monosaccharides with the exception of fructose, although all the strains produced abundant growth on this carbohydrate medium. Most strains produced little or no acid from the disaccharides; maltose, lactose, and sucrose. The last named sugar supported the most abundant growth of the three. Dextrin did not serve as a carbon source for any of the *Rhizobium* or *Agrobacterium* species tested.

In contrast to the above results, Baldwin and Fred (3) reported that many strains of rhizobia produced acid from disaccharides and that *A. radiobacter* formed acid in media containing dextrin. In the results obtained here, neither the strains of rhizobia nor the three strains of *Agrobacterium* species showed growth with dextrin as the sole source of carbon. When dextrin was autoclaved in the basal medium, as done by Baldwin and Fred, their results were duplicated exactly. It seems possible, therefore, that *A. radiobacter* does not ferment dextrin but may form acid from degradation products of dextrin resulting from heat sterilization.

Plant Tests

The strains of caragana rhizobia also varied greatly in their ability to fix nitrogen symbiotically (Figs. 1 and 2). Strain 1035 failed to nodulate its parent host. This strain was culturally typical of rhizobia, however, and in later plant inoculation tests, formed nodules on some other leguminous species (Table II). The other strains readily nodulated caragana plants but showed all gradations of effectiveness. Eight strains of caragana rhizobia which differed greatly in geographic origin and in cultural characteristics were used in the cross-inoculation studies. Each of these strains, namely: 726, 728, 729, 1030, 1031, 1032, 1033, and 1035, was tested in duplicate jars for its ability to nodulate the following species: *Lupinus angustifolius* L., *Glycine max* Merr., *Pisum sativum* Poir., *Medicago sativa* L., *Lotus uliginosus* Hoffm., *Lotus corniculatus* L., *Robinia pseudo-acacia* L., *Phaseolus vulgaris* L., *Colutea*

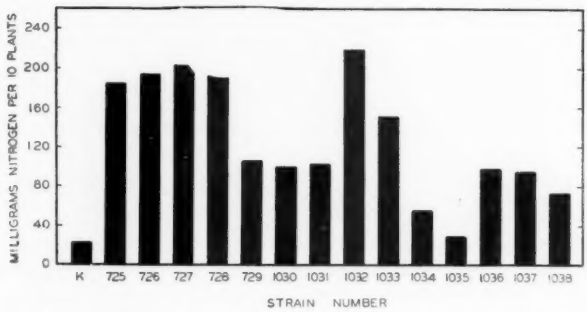

FIG. 1. Strain variation of rhizobia in symbiosis with *Caragana arborescens* L.

arborescens L., *Lespedeza stipulacea* Maxim., and *Trifolium pratense* L. In addition, each of the aforementioned species was also inoculated with a strain of rhizobia from its homologous cross-inoculation group (Table II).

In no case were the noninoculated control plants nodulated. With the exception of *L. stipulacea* which was not nodulated by cowpea strain 611, all species were nodulated by their homologous rhizobia. None of the eight strains of rhizobia caused the formation of nodules on *L. angustifolius*, *G. max*, *P. sativum*, *M. sativa*, and *L. uliginosus*. These strains showed uniformity, however, in their ability to form nodules on *L. corniculatus*, *R. pseudo-acacia*, *P. vulgaris*, *Colutea arborescens*, *L. stipulacea*, and *T. pratense*. Exceptions to this uniformity of plant response were: (*a*) strain 1035 failed to nodulate both its parent host plant and *T. pratense* and (*b*) strains 1035 and 729 sparingly nodulated *R. pseudo-acacia*. All plants were grown in cotton-stoppered bottles except *L. angustifolius*, *P. vulgaris*, *G. max*, and *P. sativum*, which, because of their large size, were grown in open jars. Each of two plants of *G. max* inoculated with strain 1033 possessed one nodule but since these plants were exposed to the greenhouse air, contamination probably accounted for this scant nodulation. Plants of *Lotus corniculatus* inoculated with caragana rhizobia were much larger and greener than the noninoculated plants, but none of the other species of Leguminosae tested showed visible benefit from their association with these bacteria.

Since the above results showed that these strains of rhizobia from *C. arborescens* formed nodules on the plants included in six different cross-inoculation groups, it was deemed advisable to make reisolations from the nodules of these plants for confirmation of the identity of the strains. In consequence, four strains were reisolated from *Colutea arborescens*, four from *T. pratense*, four from *L. corniculatus*, and two strains from *R. pseudo-acacia*. The wide diversity of cultural and physiological characteristics shown by the caragana rhizobia facilitated the accurate identification of each strain on reisolation from these plants. Without exception the reisolated strains showed the identical growth rates, litmus milk reactions, and acid production from the 12 carbohydrates previously employed, as did the original cultures.

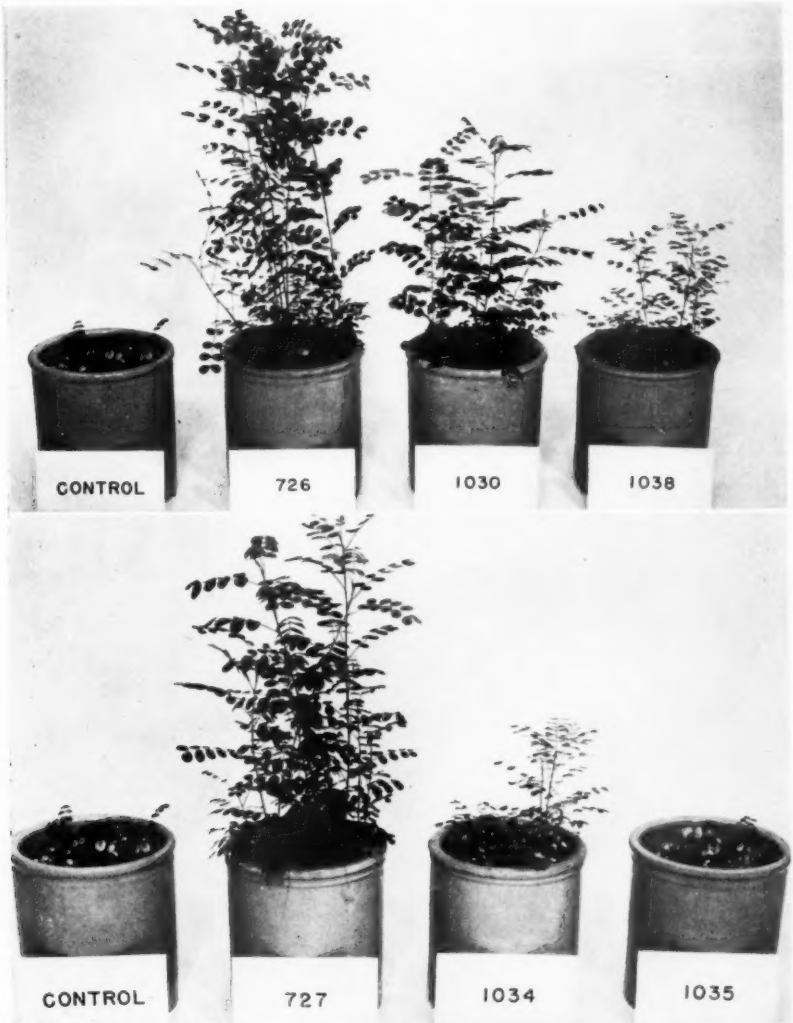

FIG. 2. Strain variation of selected cultures of rhizobia in symbiosis with *Caragana arborescens* L.

TABLE II

PERCENTAGE OF TOTAL TEST PLANTS OF EACH SPECIES NODULATED BY STRAINS OF RHIZOBIA FROM *Caragana arborescens* L.

Strain number	Plant species tested											
	Caragana arborescens	*Phaseolus vulgaris*	*Lupinus angustifolius*	*Glycine max*	*Pisum salivum*	*Medicago saliva*	*Lotus uliginosus*	*Lotus corniculatus*	*Colutea arborescens*	*Robinia pseudo-acacia*	*Lespedeza stipulacea*	*Trifolium pratense*
726	100	92	0	0	0	0	0	100	57	0	82	44
728	100	93	0	0	0	0	0	100	16	0	95	33
729	100	100	0	0	0	0	0	100	33	14	76	40
1030	100	100	0	0	0	0	0	100	0	0	94	33
1031	100	100	0	0	0	0	0	100	33	0	68	58
1032	100	100	0	0	0	0	0	100	20	0	65	28
1033	100	93	0	14	0	0	0	100	16	0	89	50
1035	0	100	0	0	0	0	0	11	50	12	20	0
Homologous strain		100	100	100	100	100	88	100	33	86	0	100

In reciprocal tests, 30 strains of rhizobia, isolated from 20 species contained in 15 leguminous genera, were used as inocula on surface-sterilized seeds of *C. arborescens* (Table III). The host plants of these strains are included in 10 of the currently recognized cross-inoculation groups. None of these strains nodulated *C. arborescens*, although the parent hosts of nine of these strains were nodulated by the caragana rhizobia.

TABLE III

NONRECIPROCAL CROSS-INOCULATIONS BETWEEN *Caragana arborescens* AND OTHER SPECIES OF LEGUMINOSAE

Species nodulated by caragana rhizobia	Strains of rhizobia which did not nodulate *C. arborescens*
Trifolium pratense	*R. meliloti* 107, 115, 127, 138
Phaseolus vulgaris	*R. trifolii* 202, 205, 210, 227
Lotus corniculatus	*R. leguminosarum* 308, 312, 326, 341
Colutea arborescens	*R. phaseoli* 403, 412
Robinia pseudo-acacia	*R. japonicum* 505, 507, 510, 521
Lespedeza stipulacea	*R. lupini* 804, 807, 810, 814
	Cowpea rhizobia 611, 625, 628, 644
	Colutea arborescens 751
	Robinia pseudo-acacia 755
	Lotus corniculatus 850
	Lotus uliginosus 852

Rhizobia reisolated from nodules formed on *T. pratense* by caragana strains 726, 728, 1031, and 1033, and from nodules formed on *Colutea arborescens* by caragana strains 729, 1031, and 1033, showed no significant changes in their ability to symbiose with their original host plant. These results showed that at least a brief association of caragana rhizobia with these alternate host plants did not account for the observed lack of reciprocal cross-inoculation.

Discussion

The wide variation in cultural and physiological reactions among individual strains of caragana rhizobia indicated that they are a rather heterogeneous group. On the basis of this study, it was not possible to classify rhizobia from *Caragana arborescens* according to the criteria commonly used for the identification of *Rhizobium* spp. Cultural characteristics appeared to be of even less value for the classification of these bacteria than they are for the delimitation of other species of rhizobia. Indeed, on the basis of cultural characteristics, certain strains may be included in each of the preliminary subdivisions of rhizobia as contained in Bergey's Manual of Determinative Bacteriology (4).

As was indicated by the greenhouse tests, the results from the plant specificity studies showed similar complications. On one hand, these strains nodulated species of the family Leguminosae now included in the clover, bean,

lotus, cowpea, and locust cross-inoculation groups. On the other hand, none of the cultures tested which were isolated from plants in these groups formed nodules on caragana. Presumably an interchange of rhizobia between *C. arborescens* and other species of Leguminosae, such as shown experimentally here, occurs under natural conditions. Thus red clover, growing near *C. arborescens*, might be nodulated by rhizobia normally symbiosing with the latter species. It is probable, therefore, that if a large enough number of strains isolated from *T. pratense*, *Colutea arborescens*, or other species nodulated by caragana rhizobia were tested, one would find strains capable of forming nodules on *Caragana arborescens*.

As shown in Table II, all the strains of rhizobia from *C. arborescens* showed a nearly identical spectrum of host specificities on the plants tested. This uniformity in the infective pattern of these strains was in sharp contrast to the wide variations which occurred in their cultural and physiological characteristics.

The reciprocal tests indicated that *C. arborescens* is restrictive in the number of strains with which it symbioses, since the 30 strains of rhizobia from 20 diverse leguminous species tested failed to form nodules on this species. An examination of the flowers of the Siberian pea tree showed that their structure favors self-pollination. Thus, the tendency for this plant to symbiose with only a limited number of strains of rhizobia agrees well with the observations of Wilson (11) who found that highly self-pollinating species of Leguminosae either did not bear nodules or symbiosed with only a limited number of strains of rhizobia. The strains of rhizobia symbiosing with a highly self-pollinating leguminous plant were also reported to be very similar in cultural and physiological reactions.

Although the strains of rhizobia from *C. arborescens* studied were dissimilar in their physiological characteristics, they appeared to be very closely related in their pattern of host-plant specificities. However, admittedly, the rhizobia from many species of highly self-pollinating plants should be studied before any general conclusions can be made.

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PRELIMINARY STUDIES IN *ASCOCHYTA PISI* LIB.[1]

By Donald Brewer and Blair H. MacNeill[2]

Abstract

Foliage infection of pea by *Ascochyta pisi* Lib. is accomplished by direct penetration of the cuticle without the formation of an appressorium. Subsequent colonization is at first subcuticular, then intercellular, resulting in the collapse and death of the host cells. No haustoria are formed. Resistance may be due in part to the cuticular barrier as well as to a physiologic factor which limits the colonization of the host once penetration has been effected. Pycnidial formation is symphogenous. Spores are produced singly from conidiophores that grow out from the inner wall cells of the pycnidium. Each spore is two-celled, and each cell contains but one nucleus. A single nuclear division occurs early in the ontogeny of the spore so that most spores even prior to germination have binucleate cells. Spore production is marked by the almost complete depletion of the protoplasmic content of the fungal mass; as a consequence vegetative development of the mycelium ceases and the focus of infection becomes localized as a leaf spot. It is suggested that the production of this discrete type of lesion by *A. pisi* and certain other pycnidiaceous leaf-spotting fungi is, mainly, a function of the developmental rhythm of the fungus, and, accordingly, is not the expression of a specific host-parasite interaction.

Introduction

Three closely related organisms, *Mycosphaerella pinodes* (Berk. and Blox.) Stone, *Ascochyta pinodella* Jones, and *Ascochyta pisi* Lib. have been reported as contributing collectively to the so-called Ascochyta blight of peas. In Ontario, Ascochyta blight is due largely to the activity of *A. pisi*. This organism may be found on blighted pea foliage throughout our entire canning crop area, and has been reported by Wallen and Skolko (9) to be rather consistently isolated from pea seed produced in this province. The *A. pisi* disease is characterized by the production of discrete lesions, each of which is sharply delimited by a halo of brown necrotic tissue, upon the leaves and stems of young pea plants. Secondary attacks upon the pods by pycnidiospores released from lesions on the foliage result in the infection of the developing seed. Recent efforts undertaken in Canada, Australia, and Russia to combat this Ascochyta disease have been through the breeding of resistant varieties of peas.

In the present investigations a study of the nature of resistance to *A. pisi* was made through observations on the host–parasite interactions during leaf infection. In addition, some study of the nuclear cytology of the pathogen was carried out with the object of determining the origin of variability encountered amongst the various isolates.

Materials

The pea varieties used in these investigations varied from those extremely susceptible to *A. pisi* to those highly resistant, and included Thomas Laxton,

[1] *Manuscript received July 22, 1953.*
Contribution of the Department of Botany, Ontario Agricultural College, Guelph, Ont. Based in part on a thesis submitted by the first named author in partial fulfillment of the requirements for the degree of Master of Science in Agriculture.
[2] *Associate Professor of Botany.*

Wisconsin Early, Alaska, Lincoln, O.A.C. 181, and A.100. The latter variety, developed at Ottawa, proved to be immune under our experimental conditions.

The isolate of *A. pisi* used was obtained from pea seed collected in Western Canada.

Methods

Moisture Relationships

Drops of aqueous spore suspension were allowed to dry on glass cover slips which were then placed over van Tieghem cells in which various relative humidities were maintained by the sulphuric acid method, in accordance with the table supplied by Stevens (7).

Inoculation

Inoculation was accomplished by atomizing the plants with a suspension of spores made by flooding an abundantly sporulating seven-day-old culture with water. After the plants were atomized, they were transferred to a moist chamber which was supplied with a constant, very fine mist of water so as to maintain the atmosphere at saturation. The incubation period in this chamber varied from 3 to 72 hr., depending upon the nature of the experiment. To obtain material for microscopic examination of infected leaves, the plants were left in the chamber for 24 hr.

Histopathology

For the purpose of studying leaf penetration and colonization of foliage tissue, pea varieties varying from susceptible to extremely resistant were used. Such plants were incubated in a moist chamber for 24 hr. after inoculation and then returned to ordinary greenhouse conditions. Samples of inoculated leaves were collected at daily intervals, and microscopic examination was made of both cross sections and surface views.

Material for surface examination was placed, immediately upon being collected, in a mixture of equal parts of 95% ethyl alcohol and glacial acetic acid. This procedure served to kill and fix the spores as well as clear the leaves. Whole leaves or portions of leaves were then mounted in lactophenol – cotton blue on a glass slide and examined under the microscope. This technique produced a clear leaf with the spores and germ tubes external to the leaf tissue showing a very intense blue, and the internal hyphae almost colorless by contrast.

Leaves to be used for microtome sectioning were collected at regular intervals subsequent to inoculation and fixed in a mixture containing 10 parts formalin, 5 parts propionic acid, 50 parts 95% ethyl alcohol, and 35 parts distilled water. Following this, the material was dehydrated through a schedule utilizing tertiary butyl alcohol, then embedded in Fisher's Tissuemat, and stained by Stoughton's technique (8) using thionin and orange G. Such embedded material was used only to confirm the observations made earlier upon fresh material.

Cytology

The Feulgen technique using leuco basic fuchsin was employed in all the nuclear investigations reported here.

Spores for examination were obtained by squashing pycnidia on a slide, then treating the preparation for 10 min. with Semen's fixative (six parts absolute alcohol, one part glacial acetic acid, and three parts chloroform). The most satisfactory hydrolyzing time was found to be five minutes in 1 *N* hydrochloric acid at 60° C.

Studies upon the formation of the pycnidium were carried out with the aid of slide cultures. The preparation of these cultures entailed the coating of sterile glass slides with a thin layer of agar medium, inoculating the medium with a spore suspension, and incubating in sterile Petri dishes. At various intervals of time after inoculation, the material was treated with Karpochenko's fixative (4), hydrolyzed for 10 min. in 1 *N* hydrochloric acid, and stained by the Feulgen technique.

Results

Moisture Requirements for Spore Germination

Free water was found to be essential for the vigorous germination of the spores of *A. pisi*, although some weak germination was observed to occur at 100% relative humidity. In free water at 25° C. the spores germinated within three to four hours.

Moisture Requirements for Foliage Infection

A minimum exposure of six hours at saturation was required to bring about infection of pea foliage. A further extension of time at saturation increased the number of lesions developing per plant, but exposures longer than 24 hr. did not affect the amount of infection to any noticeable extent. Plants developed macroscopic symptoms within five to six days after being removed from the incubation chamber to ordinary greenhouse conditions. These results are in agreement with those of Hare and Walker (2).

Macroscopic Expression of Resistance

The simultaneous inoculation of varieties Thomas Laxton, Wisconsin Early, Alaska, Lincoln, O.A.C. 181, and A-100 revealed marked differences in disease development after 24 hr. incubation at saturation. In both Wisconsin Early and Thomas Laxton, considered here as extremely susceptible, lesion production was heavy, while Lincoln, a slightly resistant variety, developed relatively few lesions per leaf. On the semiresistant variety O.A.C. 181, only the occasional leaf spot was observed, and in A-100 no infection occurred at all.

Beyond this rather obvious quantitative difference in resistance among the test varieties of peas, a more subtle qualitative difference in disease expression was observed between the reactions of Alaska and Wisconsin Early. In these instances it was noted that while Alaska came, eventually, to be as heavily infected as the extremely susceptible Wisconsin Early, yet the rate of lesion

development upon the former plant was retarded, and the maturation of pycnidia displaced, in some plants, by as much as two days.

Penetration Studies

Microscopic examination of inoculated leaves of the susceptible variety Thomas Laxton and the semiresistant O.A.C. 181 revealed that germination of the spores occurred within the 24-hr. incubation period, but penetration of the tissues did not occur until the second day, and then only occasionally. By the third day, however, numerous penetrations were readily found on the leaves of both hosts.

In all instances entrance into the leaf was effected by direct attack upon the cuticle without the formation of an appressorium, and occurred at a time when the germ tubes were approximately three times the length of the spore. Penetration of the variety A-100 was not observed to occur.

Colonization of Leaf Tissue

The surface examination of infected leaves revealed that, subsequent to penetration, the hyphae travel for a considerable distance in a subcuticular locus, but on reaching the juncture of two epidermal cells they proceed downward along the line of the middle lamella (5). This initiation of subepidermal colonization does not, however, appear to limit the lateral spread of the fungus as hyphal strands were observed to continue their subcuticular progress for some distance.

Examination of cross sections of similar leaf material substantiated the above observations made upon whole leaf mounts. Even in the early stages of colonization, while the hyphae are still in their subcuticular locus, there is evidence of host–parasite interaction as the epidermal cells become plasmolyzed and finally collapse. Following this, as the mycelium ramifies among the palisade and mesophyll cells, there is a rapid attack upon the tissue underlying the area of penetration, accompanied by a marked collapse and death of all the cells in the center of the infected area. In no case was there evidence of the production of haustoria, although on occasions the mycelium entered what appeared to be living cells.

Whatever may be the mechanism by which the fungus attacks the cells from its intercellular locus it is not one of action in advance of the mycelium. Rather, cells not in contact with the hyphae appear normal, and it has been observed in some leaves with relatively mature lesions, that hyphal strands may progress even beyond the colored demarcation zone by which the necrotic area of the lesion is contained. A detailed examination of the demarcation zone, which, from macroscopic symptoms appears very abrupt, suggests that the cells are in a plesionecrotic state, and so represent but a transition from healthy to necrotic tissue. There is, then, no histological evidence of any specific host–parasite interaction which might produce a barrier to the lateral spread of the fungus or restrict lesion development to the typical discrete spot. However, when cross sections of lesions were stained with gentian violet, destained in absolute ethyl alcohol, and counterstained with orange G, only

the mycelium and spores of the fungous fruiting body retained the stain, while strands of hyphae at the periphery of the lesion were colorless as though they were devoid of contents. Maturation of fruiting bodies and the production of spores apparently exhausts the protoplasmic content of the mycelium and growth consequently ceases. Possibly this accounts for the rather restricted character of the leaf spots even in the infection of extremely susceptible hosts.

Cytological Studies

The mycelium of *A. pisi* is septate, with two to eight nuclei per cell. Anastomosis of hyphal strands was not observed during the vegetative phase of the fungus, but rather occurred only upon the initiation of fruiting body formation. Pycnidial formation is symphogenous as Kempton (3) found for certain species of *Septoria* and *Sphaeropsis*, and involves the grouping together and fusing of a number of hyphal strands into a heterogeneous mass which is the pycnidial initial. From this mass the pycnidial wall develops, after which the central portion deliquesces, forming a matrix in which the spores are exuded from the ostiole.

The spores, which are produced singly from a layer of conidiophores that grow out from the inner wall cells of the pycnidium, are two-celled. Since single-celled spores were never found even in mounts of crushed pycnidia, it would appear that the formation of the cross wall in the spore occurs very early in the development on the conidiophore. Originally each cell of the spore is uninucleate, as previously reported by Ludwig (5), but the nucleus soon divides, and most spores prior to germination have binucleate cells. The nuclear condition of the conidiophores from which the spores arise was not determined.

Discussion

Earlier studies by Ludwig (5) and Hare and Walker (2) indicated that entrance into the leaf by *A. pisi* was accomplished by direct rupture of the cuticle. To what extent then might the resistance of the host be correlated with the inability of the pathogen to negotiate this cuticular barrier?

It appears from these present investigations that the variety A-100 remains disease-free either because of some factor associated with its cuticle which prevents penetration from taking place, or because of some physiologic factor that is effective immediately after penetration of the cuticle. With the semi-resistant variety O.A.C. 181, however, penetrations occur as frequently as on the susceptible host Thomas Laxton, yet infection is light with only the occasional lesion developing on the foliage. In this instance the cuticle does not constitute a barrier to the fungus; accordingly, resistance must be considered to be due entirely to some physiologic factor within the host, which, brought to bear soon after penetration of the cuticle, tends to limit colonization to the incipient stage.

Ludwig in his studies of host infection states that there is no evidence of the existence of hyphae beyond the delimiting barrier of the lesion. The present studies indicate, however, that this so-called barrier does not restrict

the fungus in the sense that it represents a defense reaction initiated in the host, but rather seems to be but an intermediate stage in the colonization of the host tissues whereby cells, as they become affected, turn brown and finally collapse, as have those in the central part of the lesion. Viable hyphae, then, not only extend through the tissues of this plesionecrotic zone, but at the outside limit of their growth apparently lie between normal cells. A similar type of host–parasite relationship was reported by Cunningham (1) in his study of certain leaf-spotting fungi. He observed that in by far the larger number of the diseases studied no definite cicatrice was formed which might isolate the infected portion of the lesion from the healthy tissue.

Just why many necrogenic fungi parasitic upon the leaves of plants should make such limited growth resulting in the production of discrete lesions or spots has not been satisfactorily explained. In this regard our observations suggest that unlimited vegetative expansion of *A. pisi* is no longer possible once sporulation has occurred. The full cycle of the fungus, culminating in the production of spores, appears to bring about a certain depletion of the protoplasmic content of the fungal mass, and accordingly growth ceases. This type of behavior has also been observed for *Septoria lycopersici* (6), another pycnidiaceous leaf-spotting fungus. In these instances the production of a leaf spot upon a susceptible host appears to be associated with the developmental rhythm of the fungus and accordingly reflects the character of the pathogen rather than being representative of any specific expression of the host–parasite interaction.

While in the cytological investigations reported here it was demonstrated that each cell of the spores of *A. pisi* is uninucleate, the exact origin of the nuclei was not determined. The technique used did not reveal any young unicellular, uninucleate spores, nor did it permit a demonstration of the nuclear condition of the conidiophores. Thus, whether the cells of the spores contain sister nuclei or not is unknown; consequently any explanation of the origin of variability among or within single spore isolates of the organism must await further study.

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STUDIES IN WOOD-INHABITING HYMENOMYCETES

I. *ODONTIA BICOLOR*[1]

By Mildred K. Nobles[2]

Abstract

It has been found by cultural methods that *Odontia bicolor* (Alb. & Schw. ex Fries) Bres. is the cause of an important butt rot in various species of coniferous and broad-leaved trees in Canada. A description of the cultural characters of the fungus and the decay from which it has been isolated is presented.

Introduction

The sporophores of *Odontia bicolor* (Alb. & Schw. ex Fries) Bres. have been well described by Bourdot and Galzin (3), Miller (6), Brown (4), and by Miller and Boyle (7), who state that "the species is readily recognized by its characteristic cystidia" (Fig. 6). The records indicate that the fungus is widely distributed in Europe and North America and that it occurs on many species of coniferous and broad-leaved trees. Its association with an important white stringy butt rot in balsam fir has been demonstrated recently by the work of Basham, Mook, and Davidson (1). They state that cultures of the species were described by Fritz (5) under "Balsam rot, Type B, Fungus 3" which she has since recognized as *O. bicolor*. She described the mycelium as composed of hyphae with clamp connections and noted that "Scattered throughout the mycelium were numerous bunches of small crystals" but made no mention of cystidia. Brown (4) obtained single spore cultures of *O. bicolor* and found them to consist of simple-septate hyphae which fragmented to form "short rodlike segments". He recorded that the hyphae had "occasional irregular swellings" but did not recognize cystidia. He paired three single spore cultures in all possible combinations and found that hyphae bearing clamp connections were formed in one combination, which indicated that the fungus is heterothallic.

Recently large numbers of cultures have been isolated from decays in various species of coniferous and broad-leaved trees during investigations by members of the Laboratories of Forest Pathology in Canada and have been submitted to the author for identification. These included a group with cultural characters, of which the most prominent was the presence of capitate, incrusted cystidia, which were somewhat similar to those described for *Polyporus abietinus* Dicks. ex Fries (8). On the assumption that cultures of *P. abietinus* could exhibit a range in characters wide enough to include the isolates from decay, they were assigned to that species. On the basis of this identification Bier, Salisbury, and Waldie (2), in their report on decay in *Abies* spp. in the

[1] *Manuscript received July 8, 1953.*

Contribution No. 1287 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] *Mycologist, Ottawa, Ont.*

Upper Fraser Region of British Columbia, attributed 45 infections to *P. abietinus*. They commented that this was "of interest" since these infections were all in heartwood in living trees while the rot known to be caused by *P. abietinus* occurs in dead sapwood. The differences between the cultures from the rots and those of *P. abietinus* and between the rots from which they were isolated and those caused by *P. abietinus* cast doubt on the validity of the identification and further attempts to determine the fungus were made. It was known that cystidia bearing large caps of crystals similar to those found in the isolates from decay occur in the hymenium of *Odontia bicolor* and cultures from sporophores of this species were obtained from the Department of Botany, University of Toronto, through the kindness of the late Prof. H. S. Jackson. A comparison of these with the cultures from heartrot previously determined as *Polyporus abietinus* showed that they were identical. The association of *Odontia bicolor* with decay in the heartwood of living trees was thus demonstrated.

Methods

Up to the end of 1952, 184 cultures were isolated from decays in living trees belonging to 13 species and identified as *Odontia bicolor*. This suggests that cultures of the species may be encountered frequently during decay studies on many species and indicates the need for a published description of the cultural characters of the species. These characters were determined according to the procedure described by the author in a previous publication (8) and the description and key pattern have been prepared in conformity with those presented in that paper. In brief, the cultures were grown in 2% Difco malt agar in Petri dishes in the dark, at room temperature, records of their macroscopic characters being made at weekly intervals and of their microscopic characters at suitable times. In addition, they were grown on malt agar to which 0.5% gallic or tannic acid had been added and the presence or absence of diffusion zones and the amount of growth noted at the end of one week.

Description of Culture

Odontia bicolor (Alb. & Schw. ex Fries) Bres.

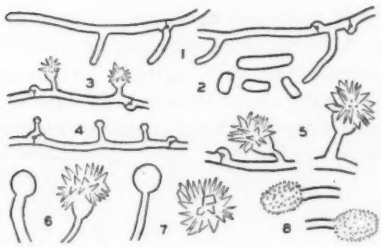
KEY PATTERN: (1,2) 1 1 1 1 2 2 (1,2) (2,3) 2 3

CULTURES EXAMINED:

CANADA.—Ontario: Barry's Bay, from decay in *Pinus strobus*, 21349; Beaverton, on *Larix laricina*, 17746; Lake Timagami, on *Betula* sp., 17748. British Columbia: Prince George, from decay in *Picea glauca*, 21049; Skutz Falls, from decay in *Pinus monticola*, 21032, from decay in *Tsuga heterophylla*, 21033.

CULTURAL CHARACTERS: (Figs. 1 to 5, 9 to 11)

GROWTH CHARACTERS.—Growth moderately rapid to slow, plates covered in three to six, usually four to five, weeks. Advancing zone even, hyaline and appressed in narrow zone or, more rarely, with slightly raised aerial mycelium



FIGS. 1 TO 7. *Odontia bicolor*.
FIG. 1. Hyphae from advancing zone. FIG. 2. Oidia. FIGS. 3 TO 7. Capitate cystidia. FIGS. 3 TO 5. Cystidia from aerial mycelium. FIG. 6. Cystidia from fruit body. FIG. 7. Cystidium and crystals from mycelium in decay. FIG. 8. *Polyporus abietinus*. Cystidia from culture. FIGS. 1, 3, 4. ×455. FIGS. 2, 5 to 8. ×800.

to limit of growth. Mat white, appressed, downy to fine woolly, in some isolates with long, cottony fibers extending from inoculum and growing against side wall of Petri dish after one week, collapsing and disappearing later, occasionally with branching and anastomosing veinlike lines of slightly more compact growth on older part of mat, becoming narrowly zonate after two or more weeks over whole surface or in newer growth only, this appearance resulting from narrow zones of more compact growth within the agar, all so thin as to be translucent. Reverse bleached, imparting milky white color to culture. No odor. On gallic acid agar diffusion zone moderately strong to strong, no growth; on tannic acid agar diffusion zone weak to moderately strong, diameter up to 2.5 cm.

HYPHAL CHARACTERS.—*Advancing zone:* hyphae hyaline, nodose-septate 1.8–4.6μ diameter. *Aerial mycelium:* (*a*) hyphae as in advancing zone, frequently aggregated into small strands; (*b*) cystidia numerous, each consisting of a short stalk borne at right angles to parent hypha or terminally, up to 15.0μ in length, narrow, with tip slightly expanded, up to 3.1–5.0μ diameter, bearing cap of coarse, jagged, crystalline material up to 23.0μ diameter, which usually becomes detached in mounts for microscopic examination; (*c*) oidia rare or apparently lacking, about 1.8μ diameter, of varying lengths. *Submerged mycelium:* hyphae as in advancing zone.

It will be observed that cultures of *Odontia bicolor* may vary in three of the characters used in diagnosis and that its key pattern denotes these possible variations by (1,2) in Column one, indicating occurrence on broad-leaved and coniferous trees, by (1,2) in Column eight, indicating presence or absence of oidia, and by (2, 3) in Column nine, indicating growth rates from moderately rapid to slow. Since provision must be made for all possible combinations of the variable characters, eight key patterns for *Odontia bicolor* must be interpolated in the numerical key published previously by the author (8). None of these coincide with key patterns of other species included in the key so that, if the insertions are made, no difficulty should be experienced in identifying cultures of *O. bicolor*.

In practice it is rarely necessary to follow the procedure outlined above to identify the species. Mounts for microscopic examination of mycelium from the culture as it grows on malt agar slants in culture tubes invariably show capitate cystidia bearing the characteristic large caps of crystalline material. No comparable structures have been observed in any species other than *Polyporus abietinus*, with which cultures of *Odontia bicolor* were first confused, and *Polyporus pargamenus*, in both of which the capitate cystidia (Fig. 8) bear small persistent caps of fine crystals quite distinct from those of *Odontia bicolor*.

Type of Decay

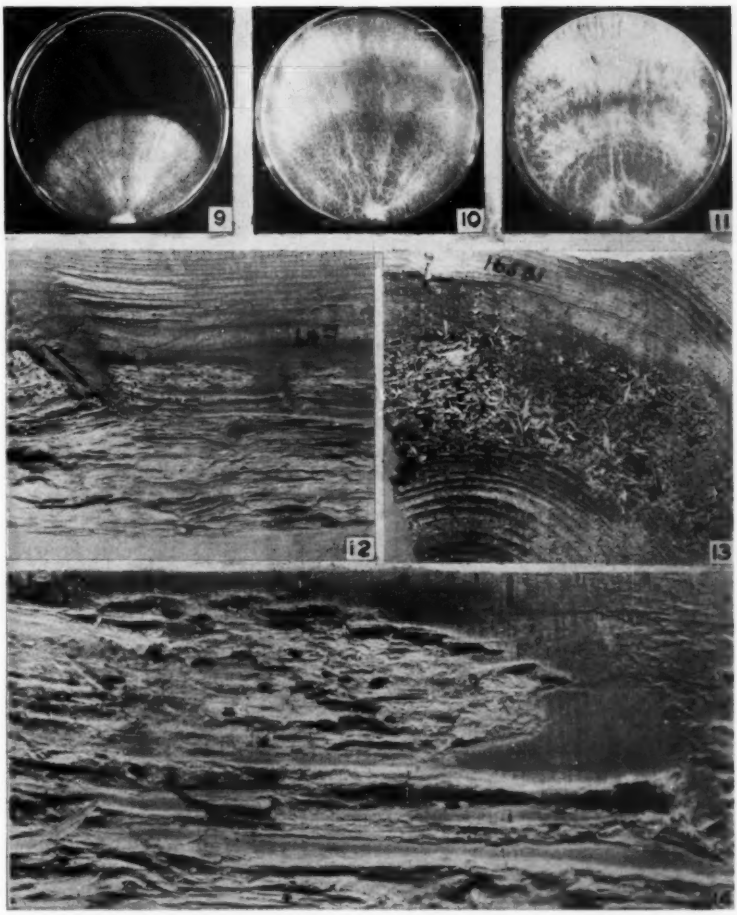
Up to the end of 1952, 184 cultures from decays in living trees belonging to the 13 species listed in Table I have been identified as *O. bicolor*. These were isolated during investigations in all provinces from Nova Scotia to British Columbia, carried out by the Laboratories of Forest Pathology at Fredericton, Toronto, Saskatoon, and Victoria. The numbers, limited as they are by the hosts studied, by the size of the samples, and by the success in making isolations, give no reliable measure of the incidence nor of the host range but indicate only that the fungus has an extensive geographic and host range. Information on the volume of decay caused by *O. bicolor* and its importance in comparison with other species that produce decay is available only for *Abies*. In their study of decay in *Abies lasiocarpa* and *A. amabilis* in the Upper Fraser region of British Columbia, Bier, Salisbury, and Waldie (2) reported it (under *Polyporus abietinus*) as second among the fungi causing butt and root rots, with 5.2% of the infections and 2.2% of the total volume of decay. Basham, Mook, and Davidson (1) in their publication on decays in balsam fir in Eastern North America listed it as second in the table showing

TABLE I

NUMBER OF CULTURES OF *Odontia bicolor* SUBMITTED BY LABORATORIES OF FOREST PATHOLOGY

Host	Fredericton	Toronto	Saskatoon	Victoria	Total
Abies amabilis				1	1
A. balsamea	35	37			72
A. lasiocarpa				56	56
Picea glauca			5	16	21
P. mariana	1	1			2
Picea spp.		7			7
Pinus monticola				1	1
P. strobus		5			5
Pseudotsuga taxifolia				2	2
Thuja plicata				1	1
Tsuga heterophylla				7	7
Betula lutea	4				4
B. papyrifera		1			1
Populus tremuloides		1			1
Populus sp.		3			3
Total	40	55	5	84	184

PLATE I



FIGS. 9 TO 14. *Odontia bicolor*.

FIGS. 9 TO 11. Culture 17748 on malt agar at two weeks, four weeks, and six weeks respectively. FIGS. 12 TO 14. Decay caused by *O. bicolor*. Fig. 12. Longitudinal section showing decay in *Pseudotsuga taxifolia*. ×3/4 approx. FIG. 13. Cross section showing decay in *Abies lasiocarpa*. ×3/4 approx. FIG. 14. Detail of Fig. 12, showing black flecks. ×1½ approx.

the frequency with which different fungi were isolated from butt rots, with isolations from 72 or 12.6% of all the butt rots from which the causal organism was isolated and identified.

The data accompanying the cultures indicate that the decay caused by *Odontia bicolor* is confined to the heartwood of butt and roots, the infection taking place through the roots and advancing from them to the basal part of the trunk. The incipient stage has been described by various investigators as pink, red, pinkish brown, or reddish brown, the advanced stage as white, of the pitted, stringy, or feather type, with black flecks. Samples of decay in *Abies balsamea*, *A. lasiocarpa*, *Picea glauca*, *P. mariana*, and *Pseudotsuga taxifolia* that yielded cultures of *Odontia bicolor* have been examined. In all, the color described for the incipient stage has faded, while the color of the more advanced stages appears paler than that of sound wood. Small isolated pits, usually with white fibrous contents, occur and these apparently may elongate and coalesce to produce a stringy rot (Figs. 12 to 14). Black flecks (Figs. 12, 14) are present in all samples, even in the small inconspicuous pockets of decay, and white mycelial felts are common. The characteristic incrusted, capitate cystidia or detached masses of crystals (Fig. 7) are usually observed in mounts for microscopic examination from the black flecks, which are composed of fungus hyphae and disintegrated wood cells, and from the mycelial felts. In final stages of decay, the wood may be completely destroyed, resulting in a hollow butt or trunk.

From the data presented it appears that *Odontia bicolor* causes a butt rot of considerable importance in a number of broad-leaved and coniferous trees and that it is widely distributed in Canada.

Acknowledgments

This study was possible only because Officers-in-Charge and members of staff of the various Laboratories of Forest Pathology, Division of Forest Biology, provided cultures and samples of decay and the author wishes to express her appreciation of their cooperation.

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AN ESTIMATE OF THE NUMBER OF ALLELES AT THE LOCI FOR HETEROTHALLISM IN A LOCAL CONCENTRATION OF *POLYPORUS OBTUSUS* BERK.[1]

By E. Eggertson[2]

Abstract

On the basis of a sample of 24 fruit bodies of *Polyporus obtusus* Berk. collected at Chalk River, Ont., in which there were found to be 39 alleles at each of the loci for heterothallism, it was estimated that the number of alleles at each of these loci in the local concentration of the fungus occurring there is 112. This agrees closely with previous estimates of the total number of alleles at these loci for the Hymenomycetes in general, and is interpreted as evidence that the local concentration of the fungus at Chalk River is not an isolated occurrence as hitherto supposed. This view is further supported by collections of the fungus in several widely scattered areas in Ontario since the initiation of this study.

Introduction

Heterothallism in the "tetrapolar" Hymenomycetes is governed by two genes located at two independent loci, at each of which there is a series of multiple alleles (6). Fertility between two monokaryons occurs when the alleles for heterothallism in the one are both different from those of the other, i.e., the resulting dikaryon is heterozygous at both loci. If the alleles of one parent monokaryon are a_1 and b_1, and those of the other a_2 and b_2, the dikaryon, including the fruit body and basidia arising from it, will have an allelic constitution of $a_1a_2b_1b_2$. The products of meiosis (the basidiospores) will be of four kinds, viz., a_1b_1, a_1b_2, a_2b_1, and a_2b_2. It is clear that these are four different mating types, and that a_1b_1 will mate with a_2b_2, a_1b_2 will mate with a_2b_1, but no other combination will be compatible. In the "bipolar" Hymenomycetes there is only one gene governing heterothallism, and hence monokaryons from a single fruit body are of only two mating types, although here, too, there is a series of multiple alleles at the locus concerned.

Within any one species of tetrapolar Hymenomycetes it is usually necessary to pair several monokaryons from different sources before two are found which, by virtue of being noncompatible, are presumed to share an allele at one or both of the loci for heterothallism. Whitehouse (6), assuming an efficient spore dispersal mechanism, as does indeed prevail in the Hymenomycetes, has postulated that "fruit-bodies collected from a limited area may, in general, be expected to carry as many different allelomorphs as those collected from widely separated localities, so long as only one fruit-body is sampled from each fungus individual". In other words, each allele is more or less uniformly distributed throughout the geographical range of the species. On the basis of an analysis of the data obtained by workers who have determined the number of alleles at these loci in small samples of fruit bodies of various

[1] *Manuscript received June 24, 1953.*
Contribution No. 105 from the Division of Forest Biology, Science Service, Department of Agriculture, Ottawa, Canada. Based on a thesis presented in April, 1953, to the University of Toronto in partial fulfillment of the requirements for the degree of Master of Arts.
[2] *Assistant Forest Biologist, Laboratory of Forest Pathology, Maple, Ontario.*

species, Whitehouse estimates that the total number of alleles for heterothallism in the populations of species of Hymenomycetes in general is "of the order of magnitude of 100 per locus".

It seems reasonable to suppose that some deviation from this apparently normal situation would be found in small, isolated, and widely separated populations of these organisms. It might be expected that the number of alleles at the loci for heterothallism in a sample of fruit bodies from such a local population would not be as great as that to be found in a sample more representative of the total population. The extent to which the number of alleles in the local population deviates from that predicted for the total population might serve as a measure of the effectiveness of whatever barrier exists between one local population and the next, or, together with information regarding mutational behavior, as an indication of the time during which the isolating barrier has been operative.

The writer's interest in this connection was raised by his familiarity with a local occurrence of the wood-destroying fungus, *Polyporus obtusus* Berk.* (Basidiomyceteae, Polyporaceae), at the Petawawa Forest Experiment Station, Chalk River, Ont., apparently isolated from all other occurrences of the same organism. It appeared desirable to make an estimate of the number of alleles at the loci for heterothallism occurring in this local population to determine whether there is, in fact, any significant deviation from the expected 100 alleles per locus. Partly as a result of the writer's interest, but not anticipated when the present study was being initiated, the status of the local concentration at Chalk River as a truly isolated occurrence of *P. obtusus* has been placed in serious doubt by collections from seven new townships in four counties and districts of southern Ontario.**

Method

In the early autumn of 1950, the writer collected a number of fruit bodies of *Polyporus obtusus* on the Petawawa Forest Experiment Station at Chalk River, Ont. Where two fruit bodies were found within about 50 ft. of one another, only one was taken, in order to prevent the accidental collection of more than one specimen of the same individual, or of specimens which, by virtue of their proximity to one another, might be suspected to be near relations. These

* Polyporus obtusus *Berk. is widely distributed in North America, occurring in localized concentrations within which it causes great destruction but outside of which it is but rarely found (5). It is also known to occur in Ceylon (3) and India (1). The synonymy of* P. obtusus *Berk. with* P. schulzeri *Fr., occurring in eastern Europe, seems somewhat uncertain. On the poor sites (mostly rocky ridges) at Chalk River,* P. obtusus *attacks the great majority of the red oaks* (Quercus borealis *Michx. f.), as well as many of the less plentiful white oaks* (Q. alba *L.) and bur oaks* (Q. macrocarpa *Michx.*). *Prior to 1949 no other collections of this fungus had been made nearer to Chalk River than at Berthierville, Que. (4),—the only other known Canadian record—and in Pennsylvania, U.S.A. (5).*

** *In addition to several collections from Chalk River, including the specimens upon which this study is based, there are deposited in the mycological herbarium of the Forest Pathology Laboratory, Maple, Ont., the following collections of* P. obtusus, *all on red oak: FPT 1468, Mattawan Twp., Nipissing Dist. (1949); FPT 1352, Papineau Twp., Nipissing Dist. (1949); FPT 1943, Franklin Twp., Muskoka Dist. (1950); FPT 1584, Sherborne Twp., Haliburton Co. (1951); FPT 2149, Hindon Twp., Haliburton Co. (1951); FPT 2162, Tiny Twp., Simcoe Co. (1952); FPT 2160, Lutterworth Twp., Haliburton Co. (1952).*

were kept in paper bags, and some three to four weeks later, in Toronto, an attempt was made to obtain from each of them a series of monosporous cultures, using a standard procedure of allowing spores from a slice of the spore-bearing surface suspended from the top of a Petri plate to drop upon the surface of nutrient agar below. It happened, however, that the fruit bodies could not be induced to discharge spores,—or, at any rate, none germinated, probably owing to the drying of the fruit bodies. A collecting trip to Chalk River during the first week in October yielded, after much searching, about 20 fruit bodies which still appeared fresh enough to discharge spores. This time the fruit bodies were placed in individual sterile covered glass jars,and kept for only two days before being treated in the same manner as the previous lot. Only two (fruit bodies D and E in this study) yielded spores which germinated on the agar. When the sporelings were readily distinguishable under the high power of the dissecting microscope, they were lifted out singly, along with a piece of the agar substrate, by means of a sterile platinum wire and placed on malt agar slants in test tubes.

The failure of the fruit bodies of this fungus to continue to discharge spores after being subjected to drought or desiccation is undoubtedly associated with their moist, spongy nature. When fresh, they may often be squeezed out like wet sponges, considerable quantities of water being expelled. Many other Hymenomycetes, their fruit bodies having a more fibrous, leathery, or corky texture, are capable of being stored under dry conditions for several weeks and later revived to discharge viable spores. In the present case, the second lot of fruit bodies collected had perhaps been subjected to frost.

Interfertility tests were carried out with the monosporous cultures from each of these two fruit bodies to ascertain the type of heterothallism. Twenty-one monosporous mycelia from fruit body D were paired in all possible combinations, and they were found to fall into four classes, as shown in Fig. 1,

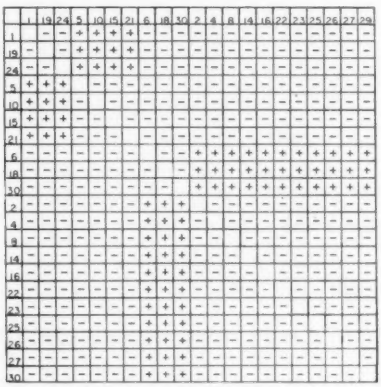

FIG. 1. Interfertility table showing the results of pairing, in all possible combinations, a series of 21 monosporous mycelia from a single fruit body, D (FPT1856), of *Polyporus obtusus* Berk.

i.e., the fungus is tetrapolar. Pairing 12 monosporous mycelia from fruit body E in all possible combinations showed that these, too, fell into four classes.

The criterion for compatibility of two monokaryotic mycelia was the formation of clamp connections in paired culture. The clamps in this species are large and very numerous, readily discernible even under the low power of the microscope. In fertile combinations a "windrow" of dikaryotic mycelium forms along the line of juncture of the two monokaryotic mycelia in most cases. When present it is very conspicuous, and is, in the writer's experience with this fungus, a positive indication that there has been a formation of the dikaryon. Absence of this phenomenon does not, unfortunately, always indicate sterility, as some fertile matings occur without its appearance, and hence all cultures have to be examined microscopically when test-crossings are being made. Fries and Jonasson (2) made reference to this ridge of dikaryotic mycelium where two compatible monokaryotic mycelia come together in *Polyporus abietinus* Dicks. ex. Fr., likening it to a (tailor's) seam.

In the autumn of 1951 fruit bodies were again collected at Chalk River. In this year few fruit bodies were produced, and only 30 specimens in good condition were collected during three days of searching. From 8 to 10 monosporous mycelia were isolated from each of 23 of these fruit bodies. When these cultures had grown sufficiently, one culture from each fruit body was crossed with every other culture from the same fruit body. This resulted, in all cases, in at least one combination developing clamps. These two compatible mycelia were then chosen as "test mycelia" for the work to follow, since they may be presumed to contain, between them, all four of the alleles for heterothallism present in the fruit body from which they were obtained.

Each of these mycelia, two from each of the 23 fruit bodies collected in 1951, and two from each of the two specimens collected the previous year,* was crossed with all the test mycelia from all the other fruit bodies. Each of these 1200 pairings was subsequently examined microscopically for the presence of clamps. All pairings in which no clamps appeared were repeated, as it was found in a few cases that one of the components of the pairing had failed to become established on the agar, most likely because of drying, and the other component had grown to occupy the whole surface. The final results are shown in Fig. 2.

Observations

It is to be presumed that a test mycelium which proved compatible in combination with every one of the other test mycelia must carry at the "*a*" locus an *a*-factor (allele) different from all the other *a*-factors in the sample, and also at the "*b*" locus a *b*-factor different from all the other *b*-factors in the sample. If, for purposes of discussion, all test mycelia which proved to be compatible with every other test mycelium in the sample are removed and the remainder rearranged so that test mycelia which are 'related' by virtue of

* *The 25 fruit bodies used in this study are deposited in the mycological herbarium of the Forest Pathology Laboratory, Maple, Ont. The accession numbers (prefixed by the letters FPT) are: 1856, 1925–1942 incl., 1944, 2144–2148 incl.*

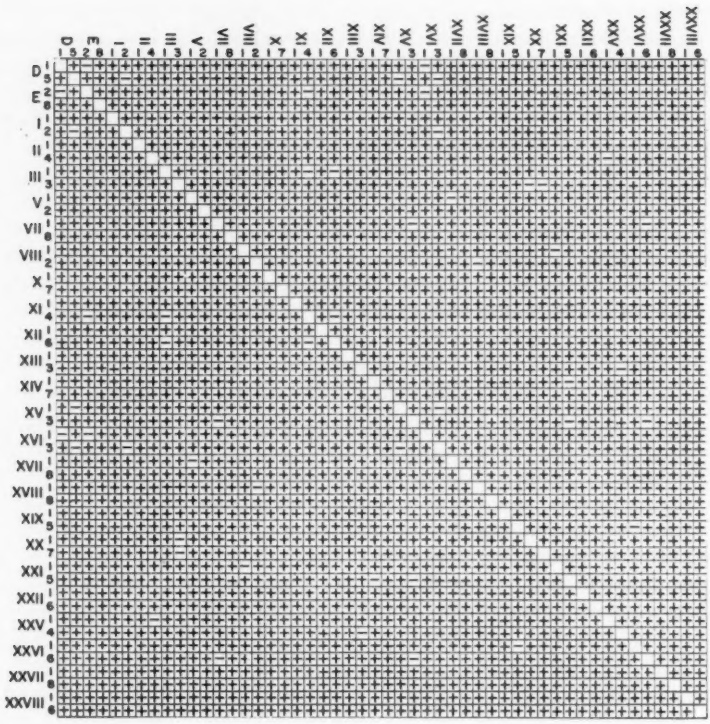

FIG. 2. Table showing the results of pairing, in all possible combinations, 25 pairs of test mycelia from 25 different fruit bodies of *Polyporus obtusus* Berk. collected at Chalk River, Ont.

sharing one or both alleles are brought together, the resulting pattern is as shown in Fig. 3. The interrelationships involved are further emphasized in Fig. 4.

In the first group of six test mycelia, it is evident that D-1 and E-2 share at least one allele for heterothallism. That they do not share alleles at both loci is shown by the fact that D-1 is compatible with XI-4, whereas E-2 is not. Apparently E-2 shares an allele at one locus with D-1 and an allele at the other locus of XI-4. If the constitution a_1b_1 is assigned to D-1, then E-2 must be a_1b_2, and XI-4 must be a_2b_2. Since III-1 shares an allele with XI-4, but not with either D-1 or E-2, its constitution must be a_2b_3. XII-6 shares an allele with III-1 and with XI-4, but not with E-2, and hence may be presumed to have the constitution a_2b_4. With the information at hand, of course, XII-6 could conceivably be a_2b_3 (i.e., identical with III-1), but this is not likely in view of the care taken in collecting the fruit bodies that the same individual not be sampled twice. In fact, a search among the extra monokaryons of

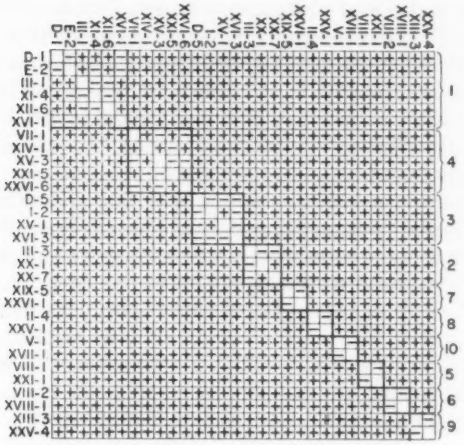

FIG. 3. Table showing a rearrangement of the results shown in Fig. 2, after deleting all test mycelia which were compatible with all other test mycelia.

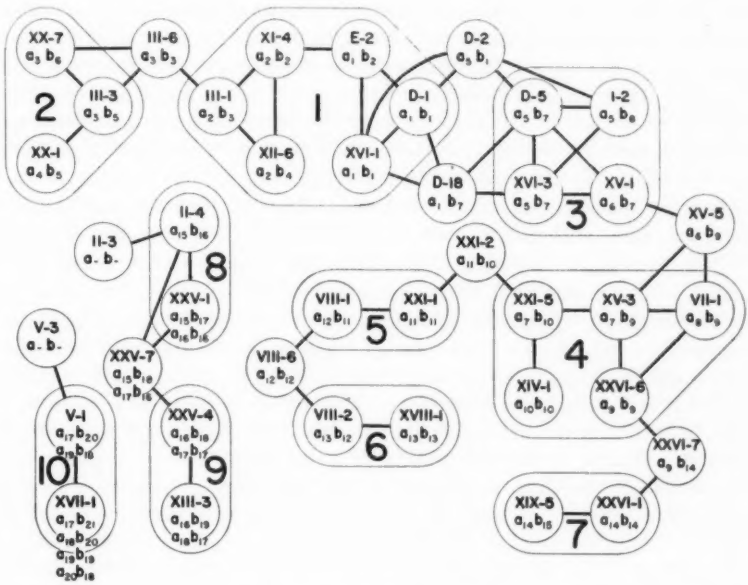

FIG. 4. Diagrammatic representation of relationships shown in Fig. 3. Each circle within the groups represents a test mycelium; the circles outside are extra monokaryons bridging the gaps between groups. A heavy connecting line indicates incompatibility between the two mycelia thus joined, i.e., the sharing of one or both alleles for heterothallism.

fruit body III revealed that at least one of them (III-6) was compatible with XII-6, but not with III-1, thus proving that XII-6 and III-1 are not identical. Only one of the four mating types of fruit body III can react in this way, and, if there had not been present in the sample of monokaryons from this fruit body a representative of this mating type, it would have been necessary to search for the appropriate mating type among the monokaryons of fruit body XII. If the desired mating type had not been found among the monokaryons of either fruit body it would have been impossible, without obtaining more monokaryons either from the original source or from fruit bodies produced in culture, to determine whether the two monokaryons in question shared one or both alleles. To produce a fruit body in culture using the two test mycelia as 'parents' and obtaining monosporous cultures from it is possible, but hardly practicable, because of the time involved. To obtain monosporous cultures from the original, by now dry, specimen is impossible. If the collections are carefully mapped so that the exact point of origin of the fruit body can be relocated, it would be possible, perhaps, to find there the following year a fruit body growing from the same dikaryotic mycelium as the original, and from it obtain the necessary additional monokaryons. Care would have to be exercised to make sure that this new fruit body contained the same alleles as the original, as the mass of mycelium proliferating within the wood of the host may be a conglomerate of many individuals resulting from multiple infection, and it would be dangerous to assume that each successive fruit body appearing at any one spot had arisen from the same initial dikaryon. As it happened, however, in this study it was possible in every case where a doubt existed whether one or both alleles were duplicated in two monokaryons to decide the issue by testing against the extra monokaryons on hand from one or the other of the two fruit bodies involved.

There is, in Group I, another such doubtful case, namely, XVI-1, which shares one allele with E-2, but may, on the face of it, share both alleles with D-1. The suspicion that this is so is all the stronger when it is noted that in Group 3, XVI-3 and D-5, complementary to XVI-1 and D-1 respectively, share both alleles. It will be remembered that fruit body D is one of the two fruit bodies from which viable spores were obtained in the 1950 collections. Fruit body XVI was collected in 1951. Since none of these collections was mapped it is quite conceivable that a 1950 collection could have been duplicated in 1951, in spite of the care that was taken to avoid duplication in each of the two years. In this instance XVI-1 was crossed with a representative (D-2 and D-18, see Fig. 1) of each of the two mating types of fruit body D not represented by D-1 and D-5. Both crosses were sterile, thus proving that XVI-1 and D-1 (a_1b_1) are identical. In Group 3, it is patent, even without such a test, that XVI-3 and D-5 are also identical. Therefore fruit body D and fruit body XVI are identical and were almost certainly collected from the same parent mycelium. This is the only such duplication in the sample collected and reduces the size of the experimental sample from 25 fruit bodies to 24.

The allelic make-up of all the monokaryons of Group 1 has now been deduced. It is clear that there are in the group only two different alleles of one of the genes for heterothallism (arbitrarily designated as the *a*-factor), but four different alleles of the other (*b*) gene. It is possible, in each case, to determine not only whether an allele is shared between two monokaryons, but also at which locus, *a* or *b*, it is situated, or whether both alleles are shared.

In Group 2, III-3, being complementary to III-1 and sharing no alleles with any monokaryons already allotted numbers, is designated as a_3b_5. XX-1 shares one allele with III-3, but with the evidence at hand it is not possible to decide the identity of the shared allele. By crossing XII-6 (a_2b_4) with extra monokaryons of fruit body III, one (III-6)* was found which was compatible with XII-6 but not with III-1 (a_2b_3). The constitution of III-6 must therefore be a_3b_3. XX-1 was found to be compatible with III-6. Hence XX-1 does not carry allele a_3, and the factor shared between XX-1 and III-3 is b_5. XX-7 also shares an allele with III-3, but not the same one that XX-1 shares with III-3. The constitution of XX-7 is hence a_3b_6.

The preceding paragraphs have illustrated the method of deducing the allelic constitution of monokaryons by (*a*) reasoning from one monokaryon to the next, chainwise, within a closed group of monokaryons which are 'related' through sharing alleles, (*b*) where necessary, testing against extra monokaryons of one of the fruit bodies concerned to determine whether two monokaryons share one or both alleles, and (*c*) bridging the gap between two groups each of which contains one of two complementary monokaryons from a single fruit body, thus ensuring a continuity of identity of the loci from one group to another. In Fig. 4, are shown all the test mycelia which shared an allele with one or more of the other test mycelia and also the extra monokaryons used in connection with items (*b*) and (*c*) above. The allelic constitution of each monokaryon is indicated. It will be noted that it was not possible to connect Groups 8, 9, and 10 to the other groups, and there is therefore more than one possible designation for all but one of the monokaryons in these groups. There are also, as a result, four different combinations of numbers of "*a*" and "*b*" alleles, respectively, in the sample, although the total number of alleles at both loci is fixed.

None of the remaining 20 monokaryons shares an allele with any other monokaryon in the sample. Each one of these must carry at each of the two loci for heterothallism, an allele different from all the other alleles in the sample. There are, therefore, in addition to the alleles already 'tagged' another 20 different "*a*" alleles and another 20 different "*b*" alleles in the sample of 24 different fruit bodies used in the investigation. The total number of alleles is therefore 78, of which 37, 38, 39, or 40 are "*a*" alleles, and 41, 40, 39, or 38, respectively, are "*b*" alleles.

No pair of these figures deviates significantly from equivalence. It is thus apparent that the numbers of alleles at the two loci for heterothallism in the wild population from which the present sample was taken are not widely

* *III-6 was also used to help determine the constitution of XII-6 (see above).*

different, and that the value of 39 for the actual number of alleles present at each of the two loci is most probably correct for this sample. Use of this figure in the formula given by Whitehouse (6) gives an estimate of 112 alleles at each of the loci for heterothallism in the total local population.

Discussion

It is evident that this study does not reveal any peculiarities with respect to the number of alleles at the loci for heterothallism present in the local population of *P. obtusus* at Chalk River. The results obtained would appear to lead to one of two conclusions.

If the local population *is* isolated it would be reasonable, perhaps, to suspect that the number of these alleles in the total population is greater than the 112 per locus found to exist at Chalk River, and hence greater than that expected from Whitehouse's prognostication (6). This possibility can only be checked by a study of the alleles contained in a suitably large sample representative of the total population, and such a study would be desirable as a check on the validity of the concept of uniform distribution of alleles throughout the range of the fungus. It is quite possible, even probable, that within the total population of *P. obtusus* there exist alleles for heterothallism not occurring at Chalk River. However, because of the progressively greater amount of time and work involved with each increase in the size of a sample of fruit bodies used, no attempt was made to increase the scope of this study to include fruit bodies from areas other than Chalk River.

The agreement between the present estimate and that of Whitehouse for populations of Hymenomycetes in general, however, is surely more than coincidental, especially in view of the size of the present sample: more than one and one-half times as large as that used by Fries and Jonasson (2), which in turn was larger than that of any previous workers. When viewed in conjunction with the recent collections of the fungus in several new areas in Ontario (see p. 751), the results obtained in this study point to a second, more acceptable, conclusion, viz., that the local population of *P. obtusus* at Chalk River is not truly isolated, or, at any rate, has not been so for any great length of time, but is merely the result of the presence there of a large quantity of the right host growing under conditions which appear to render it highly susceptible to attack. If this interpretation is correct, and presupposing, of course, the uniform distribution of these alleles throughout the geographical range of the fungus, it follows that the estimate of 112 alleles for heterothallism at each locus at Chalk River is valid also for the total population.

There are good reasons for the fungus not having been collected more frequently. Firstly, it can probably only become successfully established on a host which has been considerably weakened by adverse conditions of site. On such sites the timber is of very little economic value, and hence fungi attacking the stand are not likely to evoke much interest from timber operators, woodlot owners, or other forest workers. Secondly, the fungus appears to fruit only in occasional years, and then always toward the end of the summer

season. Casual observation appears to indicate that fruiting is contingent upon abundant moisture during, and perhaps also prior to, the production of the fruit bodies. These are very spongy and watery and soon disintegrate through the action of insects and, possibly, other fungi, or else become dry, somewhat shrunken, and of an inconspicuous pale yellowish-brown color, seldom remaining attached to the host beyond the season of their production. For these reasons it is not surprising that the fungus has not been collected in areas other than those in which obvious concentrations exist, or where persons with an interest in the collection of fungi have been active.

It would appear, then, that the previously reported peculiarities of distribution, viz., the local concentrations in which *P. obtusus* generally seems to occur, are probably determined by a low degree of parasitism which largely limits the activities of the fungus to those areas in which the host has been considerably weakened by adverse conditions, and that these local concentrations are not isolated occurrences outside of which the organism is not to be found. The writer ventures to predict that, with the increased interest and activity aroused by the initiation in 1951 of the country-wide Forest Disease Survey, *P. obtusus* will be found to be of common occurrence in Eastern Canada, especially throughout the range of the red oak, and that within this region the fungus will be found associated with this and a few other hardwood species wherever these are growing on certain unfavorable sites.

Acknowledgments

The writer wishes to acknowledge his indebtedness to Dr. L. T. White, Officer-in-Charge, Laboratory of Forest Pathology, Maple, Ont. for placing at his disposal time and facilities necessary for the completion of this study, and for his helpful criticisms and unceasing encouragement; to Dr. J. E. Bier, Head, Unit of Forest Pathology, Division of Forest Biology, Ottawa, for releasing the information contained herein for thesis purposes; to Dr. D. A. Quirke, Laboratory of Forest Pathology, Maple, and Profs. R. F. Cain and K. H. Rothfels, Department of Botany, University of Toronto, for their critical reading of the manuscript and for their helpful suggestions.

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STUDIES OF CANADIAN THELEPHORACEAE

X. SOME SPECIES OF *PENIOPHORA*, SECTION *TUBULIFERAE*

BY LUELLA K. WERESUB[2]

Abstract

In this study, species of *Peniophora* which appear to belong in the subsection*** of Bourdot and Galzin's section *Tubuliferae* are segregated on the basis of a single cystidial characteristic, namely: the solubility in 10% potassium hydroxide of thickened cystidial walls. Complete descriptions are given of six previously described species (*P. accedens, P. calothrix, P. chaetophora, P. crassa, P. juniperina, P. vermifera*) and two species proposed as new (*P. angusta, P. sceptrifera*). Also included in a provisional key are four species recently described in this series of studies (*P. hamata, P. inornata, P. prominens, P. regifica*), as well as three long-known species (*P. gracillima, P. hirtella, P. subulata*). This work is presented as introductory to a taxonomic reconsideration of the *Tubuliferae* section of the genus *Peniophora*.

Introduction

Out of the conglomeration that is the genus *Peniophora* Cke., some order has appeared: Eriksson (4) has shown that the *Coloratae* section is a homogeneous group, worthy of rank as a separate genus. Now the other sections of *Peniophora* require the same intensive study before a proper taxonomic revision can be made of the entire genus.

This paper records the beginning of an attempt to sort out the species of the section *Tubuliferae* Bourd. & Galz. Here, however, we treat of an assemblage that is, like the genus itself, a motley mixture. Bourdot and Galzin (1) subdivided it into four subsections; it was therefore thought advisable to enter into the study of the section by a thorough investigation of one of these.

The subsection *** appeared to be an appropriate starting point for study, since many of its members have been recorded as demonstrating an interesting property, namely: the solubility, in 10% potassium hydroxide, of their thickened cystidial walls. This, then, is the tentatively chosen, segregating character that is used herein as the pivot of this study.

Examination of crushed mounts and, in some cases of sections, was made in potassium hydroxide (about 0.5 to 3%) plus phloxine (about 2%), for most of the measurements and drawings, followed by flooding with 10% potassium hydroxide to demonstrate solubility. Material was also mounted in Melzer's solution* to test for amyloidity, although this property was found to be inconstant within the morphological limits set for some of the species.

Apropos of the latter comment is the following statement: only dried herbarium specimens have been studied. It would be most revealing to be

[1] *Manuscript received June 22, 1953.*

Joint contribution from the Department of Botany, University of Toronto, Toronto, Ontario (with financial assistance from the National Research Council of Canada), and the Department of Botany, University of Manitoba, Winnipeg, Man.

[2] *Assistant Professor, Department of Botany, University of Manitoba.*

* *Melzer's solution: 0.5 gm. iodine; 1.5 gm. potassium iodide; 20 gm. chloral hydrate; 20 cc. water.*

able to compare growth and morphology of these species under identical environmental conditions, if not in nature, at least in the laboratory, since it is certainly possible that what we take to be significant differences in growth characteristics and cystidial properties may be environmentally variable. It is also likely that differences which we ignore as insignificant may, under identical conditions, be emphasized to the point of helping to solve the problem of such species complexes as *P. gracillima*, etc. However, until it is possible to culture these species and conduct genetic experiments, the following survey is presented to supply a clarification of part of the picture.

Of the known species of *Peniophora* with cystidia whose smooth thickened walls are affected by potassium hydroxide, not all are dealt with here. Complete descriptions are given of eight species considered to be morphologically clear-cut; of these, six have been previously described, and two are proposed as new. Included in the accompanying key but not discussed further are four well-defined species recently described in this series of studies (6, 7), and three long-known species (*P. gracillima*, *P. hirtella*, *P. subulata*) which require additional study before they can be adequately delimited. Still others, of which I have not seen authentic material (e.g. *P. abnormis* Bourd. & Galz., *P. effugiens* Bourd. & Galz. ex Bourd. & Galz., *P. farinacea* Bourd. & Galz., etc.) are not treated at this time.

Key to some *Peniophora* spp., sect. *Tubuliferae*

1. Cystidial walls smooth, thickened at least in part, unstained by phloxine, soluble or swelling to the point of disfigurement in 5–10% KOH 2
   Cystidial walls not so affected by KOH ..... Not treated

2. Cystidia* very long, their basal septa rarely observable, immersed for the greater portion of their length in a palisade layer of very narrow basidia (2.5–3.5 μ wide at broadest point) and vertically arranged hyphae; cystidia obovate, apices more or less broadened on slender stems, stem walls very thick, with capillary lumina which usually expand more or less gradually toward the thinner walled apices; fructification frequently zonate, commonly over 1 mm. deep ..... *P. crassa* Burt V
   Cystidia, basidia, and fructification not as above; cystidial bases typically broader than stems, frequently with spreading "roots" 3

3. Majority of cystidia with lumina more or less capillary in the stem and expanded toward the apex with concomitant thinning of walls; apices sometimes encrusted, but never capped with noncrystalline structures which are apparently produced separately from the rest of the cystidium 4
   Cystidia with lumina not expanded toward the apex, or, if so, topped by noncrystalline caps, acute or obtuse, apparently produced separately from the main structure 13

4. Cystidia with bulbous apices, definitely broader than the width of the stem neck 5
   Cystidial apices not pronouncedly bulbous, rarely markedly broader than the width of the stem neck (but cf. *P. calothrix*) 8

5. Basidiospores slender cylindric, more or less curved, (4–)4.75–7.25(–8.5) × (0.75–)1.0–2.0(–2.5) μ; cystidia (3.5–)5.5–7.5(–9) μ broad near the base.
   P. juniperina Bourd. & Galz. ex Boud. & Galz. VI
   Basidiospores not slender, usually broadly ellipsoid or subcylindric to subglobose 6

6. Cystidia very slender, 1.5–3 μ wide near the base, tapering sharply to a neck width of 1.0–1.75 μ, then flaring into terminal thin-walled bulbs 4–5(–6.5) μ broad; basidiospores broadly ellipsoid, sometimes subglobose (4.0–)5–6.5 × 3–4.5 μ
   P. sceptrifera Jacks. & Were. n. sp. VII
   Cystidia mainly broader, never tapering so sharply 7

* *See Fig. 1 for explanation of terms used in describing cystidia.*

7. Cystidia slender cylindrical, 2.5–4(–5) μ broad near the base of the stem, narrowing only slightly to a neck width of 2–4 μ, terminal bulbs (4–)5–7.5(–10.5) μ broad; basidiospores subcylindric or broadly pyriform, (3–)3.5–5.5 × 2–3(–3.75) μ
P. accedens Bourd. & Galz. ex Wakef. & Pears. I

Cystidia 7.5–8.5 μ broad, stems tapering slightly, bulbs 10–12 μ wide; basidiospores broadly ellipsoid, 7–8.5 × 4.5–5.5 μ.....*P. regifica* Jacks. & Deard. (7)

8. Basidiospores subglobose, 3.5–4 × 4 μ; cystidia cylindrical or slightly tapering above, 4–4.5 μ wide, apices obtuse, thin-walled, about one-third length of cystidium
P. prominens Jacks. & Deard. (7)

Basidiospores slender or broadly cylindrical.....9

9. Cystidial apices generally more or less pointed.....10
Cystidial apices generally obtuse, though in some species tapered.....11

10. Cystidia slender, 3.5–5.5(–7.5) μ broad just above the base; stem cylindrical, apices very thin-walled, usually elongate, acuminate to acute; basidiospores 5.5–8.5 × 1.5–2.5 μ, flattened or slightly curved; fructification grayish yellow, delicate, more or less reticulate.....*P. hirtella* Bourd. & Galz. ex Bourd. & Galz. (1)

Cystidia generally broader, (4–)7.5–10.5(–15) μ; stems subulate, apices thin-walled, usually shorter, pointed or somewhat blunt, but always sharply tapered; basidiospores comparatively more slender, 6–8.5 × 1.5–2 μ; fructification creamy continuous, more or less densely cushiony.....*P. subulata* Bourd. & Galz. ex Donk (3)

11 Thickened walls of all hymenial structures—cystidia, basidia, and hyphae—usually more or less amyloid, though sometimes only cystidial walls responsive to Melzer's; cystidia typically with part of thickened wall extending like a hood along one side and over top of the otherwise more or less thin-walled apex; basidiospores cylindrical, (4.5–)5–7 × (1.5–)2–3 μ.....*P. calothrix* (Pat.) Rog. & Jacks. III

No such general amyloidity of all hymenial structures, nor hooding on cystidia; basidiospores generally more slender.....12

12. Cystidia subcylindrical, 3.5–5.5(–6) μ broad above the base, narrowing to (2.5–)3–4.5(–5.5) μ at the obtuse but tapering thin-walled apex; basidiospores slender cylindric, (6–)7–10(–11.5) × 1.5–2(–2.5) μ; fructification delicate, grayish or whitish pruinose, rarely a creamy and denser reticulum..*P. angusta* Rog. & Were. n. sp. II

Cystidia broader, 6.5–12.5 μ just above the base, more or less cylindric or somewhat tapered, sometimes suddenly indented at or above the neck; apices thin-walled, rounded to elongate obtuse; basidiospores slender cylindric, often slightly curved, 6.5–8(–9) × 1.5–2 μ; fructification creamy, continuous, dense, frequently lumpy and fissured.....*P. gracillima* Ell. & Everh. ex. Rog. & Jacks. (9)

13. Cystidia prominent, conical, pointed, (4.5)7–10(–12.5) μ broad just above the usually branching base, lumina more or less capillary throughout; basidiospores broadly ellipsoid to cylindric (4–)5–7(–7.5) × 2.25–3.5(–4) μ.....*P. chaetophora* (Hoehn.) Hoehn. & Litsch. IV

If cystidia conical and pointed, then usually sheathed in fine dendroid hyphae, and spores different; if basidiospores somewhat as above, then cystidia different, topped by convex or pointed terminal caps.....14

14. Cystidia usually sheathed in dendroid branching hyphae 0.75–1.5 μ broad; stems conical, 10–25 μ broad just above the rooting base; basidia large, 20–45 × (5–)8.5–11.5 μ; basidiospores flexuous-navicular, (10–)15–25(–30) × (3–)4–5.5 μ
P. vermifera Bourd. VIII

Cystidia topped by convex or pointed terminal caps; basidia smaller; basidiospores ellipsoid.....15

15. Cystidia tapered; stems cylindric, 4–7 μ broad; tips sheathed by acutely pointed hastate caps, these more or less resistant to KOH; basidiospores ellipsoid, 4.5–6 × 2.5–3.5 μ
P. inornata Jacks. & Rog. (6)

Cystidia obclavate, apices topped with convex terminal caps bearing 10–12 marginal downward projecting prongs, caps more or less resistant to KOH; basidiospores broadly ellipsoid, 5.5–7.5 × 4–4.5 μ.....*P. hamata* Jacks. (6)

Description of Species

I. PENIOPHORA ACCEDENS Bourd. & Galz. ex Wakef. & Pears. (Fig. 6)

P. accedens Bourd. & Galz. nov. subsp. under *P. glebulosa* Bres., Bull. Soc. Mycol. Fr. 28 : 386. [1913].

P. accedens Bourd. & Galz. ex Wakef. & Pears. Trans. Br. Mycol. Soc. VI: 140. 1920; Bourd. & Galz., Hymén. de Fr., p. 291. [1928].

Fructification white to gray to creamy, porous reticulate, delicate, pruinose, somewhat tomentose in profile under the lens, often discontinuous, with indeterminate margin, closely adnate to substratum; subiculum of clamped hyphae 1.5–2 μ wide, usually collapsed or otherwise indistinct; cystidia slender cylindric, (30–)45–65(–90) μ long, 2.5–4(–5) μ wide near the base of the stem, narrowing slightly to a neck width of 2–4 μ. . .walls nonamyloid, smooth, thick, swelling and dissolving in KOH. . . lumina capillary, expanding toward the tip with a corresponding thinning of walls to form apical bulbs 5–8.5(–10) × (4–)5–7.5(–10.5) μ; basidia clavate to subcylindric, stalked or not, usually rising perpendicular to basidiophores even when in clumps, (7–)8.5–12(–17.5) × 3.5–4.5(–5) μ, with four more or less divergent sterigmata, as much as 4 μ (sometimes 5μ) long; basidiospores when seen with apiculus at side subcylindric, somewhat flattened on that side, in other views almost pyriform, (3–)3.5–5.5 × 2–3(–3.75) μ. . .walls thin, smooth, nonamyloid.

On deciduous and coniferous wood.

Specimens Examined:

Ontario:

On *Pinus* sp. and *Abies balsamea:* Timagami: Bear Is.: Aug. 30, 1948, H. S. Jackson (TRT 22583)*; Aug. 21, 1944, H.S.J. (TRT 20031); (TRT 20025); Aug. 10, 1937, H.S.J. (TRT 11955); Long Point: Aug. 6, 1936, R. Biggs 656 (TRT 9783); Paradis Bay: July 27, 1939, H.S.J. (TRT 15001); on deciduous wood: Hogg's Hollow, Toronto: Oct. 18, 1945, E. R. Dearden (TRT 20192); Sept. 1, 1943, H.S.J. (TRT 20039); on coniferous wood: Thistletown, York Co., May 11, 1941, R. F. Cain (TRT 17008) **illustrated;** Credit Forks, Apr. 27, 1941, R. F. C. (TRT 17003); Meadowvale, Peel Co., May 1, 1941, R. F. C. (TRT 18015); Benwell Swamp, Oxford Co., Sept. 24, 1939, R.F.C. (TRT 15073); Norwich, May 29, 1939, R.F.C. (TRT 15246); (TRT 15216); Maple, Nov. 9, 1935, H.S.J. (TRT 8780); Oakland Swamp, Brant Co., Oct. 21, 1946, R.F.C. (TRT 23852); Algonquin Park, Sept. 17, 1938, H.S.J. (TRT 13581).

British Columbia: on coniferous wood: Vancouver, June 13, 1948, H.S.J. (TRT 23862).

* *Location of the specimen examined by the writer is indicated in brackets. Herbarium abbreviations used are mainly as proposed by J. Lanjouw and F. A. Stafleu, in Index Herbariorum, Part I, The Herbaria of the World, Utrecht, 1952; but note footnote re "V" numbers.*

Iowa: on coniferous log: Iowa City, May 2, 1932, D. P. Rogers 51 (TRT).

Massachusetts: on *Pinus strobus:* Blue Hill, Canton: May 26, 1936, A. M. & D. P. Rogers (TRT ex FH); May 29, 1936, A. M. & D. P. R. 723 (TRT).

Oregon: on Douglas fir: Philomath, Dec. 13, 1938, A. M. & D. P. R. 727 (TRT).

Rhode Is.: on *Tsuga canadensis:* Providence, Apr. 29, 1942, D.P.R. (TRT 23734: identified as *P. juniperina*).

France: on chestnut, Loubotis, Aveyron, April 1912, A. Galzin 11137, H. Bourdot 8780 = 8691, (NY, also TRT); Casourgnes, Tarn, July 23, 1909, Galz. 4307, Bourd. 6524 (S).

P. accedens appears to be an easily identified, clear-cut species, a member of the least troublesome group here, the species whose cystidial apices are prominently bulbous (cf. discussion following description of *P. sceptrifera*). There are instances of cystidia whose apices show little if any expansion, but these are usually few in number, possibly immature stages of the more frequent, bulbed cystidia among which they are scattered.

II. **Peniophora angusta** Rog. & Were. n. sp. (angustus (L): narrow) (Fig. 7)

Diagnosis Typi:

Fructificatio alba, tenerrima, pruinosa, effusa, ad substratum adnata, sub lente sensim poroso-reticulata; subiculo a hyphis laxis, nodoso-septatis, rigido- vel interdum crasso-tunicis, 2.5 μ lato; tunicis in KOH plus minusve inflatis interdum dilutis; cystidiis gracilibus, subcylindraceis, (20–)50–85 μ longis, prope basin 4–5.5 μ latis, apicem versus ad 2.5–3.5 μ angustatis; tunicae cystidiorum glabrae, incerte amyloideae, crassae, in KOH plus minusve dilutae, per expansionem luminis capillaris basalis versus apicem obtusam longitudine 1/8–1/2 totius, attenuatae; basidia subclavata, 9–17 × 3.5–4.5 μ; sporae angustae cylindraceae, vel interdum flexuosae, 8–10 × 1.75–2 μ, his tunicis tenuibus, glabris, non amyloideis.

Description of Species:

Fructification delicate. . .when fresh, waxy pruinose or farinose, pure white . . .when dry, grayish- or whitish-pruinose. . .closely adnate. . .under the lens more or less porous reticulate, pilose from projecting cystidia. . . rarely a creamy and denser reticulum; subiculum usually sparse, rarely substantial, loose. . .of clamped, rigid- or sometimes thick-walled hyphae 2–3μ wide, walls swelling more or less, sometimes dissolving in 10% KOH; cystidia slender, subcylindric, (20–)50–100(–135) μ long, 3.5–5.5(–6) μ broad near the base, narrowing to (2.5–)3–4.5(–5.5) μ at the apex. . .walls smooth, varying in amyloidity from negative to lightly positive, thick, thinning with a concomitant more or less gradual expansion of the basally capillary lumen, to culminate in an obtuse, thin-walled apex, (1/10–)1/8–1/3(–1/2) the length of the cystidium. . .the thickened walls sensitive to KOH, in some specimens

showing a delayed solubility especially in the upper half of the cystidium. . .the stem in some collections displaying a series of constrictions along its length; basidia subclavate, (7.5–)8.5–14(–18.5) × (2.75–)3.5–4.5 μ, bearing four slender, erect sterigmata about 4.5 μ long; basidiospores slender, cylindric, sometimes slightly broadened and somewhat curved just above the base, (6–)7–10(–11.5) × 1.5–2(–2.5) μ. . .walls thin, smooth, nonamyloid.

Specimens Examined:

Ontario: on conifer: Bear Is., L. Timagami: Aug. 5, 1937, A. J. Skolko (TRT 14005); H. S. Jackson (TRT 16757); July 15, 1938, R. F. Cain (TRT 13656); Algonquin Park: Aug. 25, 1939, R.F.C. (TRT 14469) TYPE; Norfolk Co., May 29, 1939, R.F.C. (TRT 15228).

British Columbia: on conifer: Vancouver Is.: June 23, 1948, H.S.J. (TRT 23740); June 25, 1948, H.S.J. (TRT 23738); (TRT 23739).

Oregon: on conifer, usually *Pinus contorta*, decorticate or charred: Heceta Beach: Nov. 26, 1937, A.M. & D.P. Rogers 443 (D.P.R., also TRT); D.P.R. 439 (D.P.R., also TRT); A.M. & D.P.R. 447 (D.P.R.); Chetco R., Curry Co., July 12, 1939, A.M. & D.P.R. 914 (D.P.R., also TRT); Sutton L., near Florence, Oct. 22, 1939, A.M. & D.P.R. 909 (D.P.R.); Nov. 26, 1937, D.P.R. 418 (D.P.R., also TRT); on foliose liverwort and *P. contorta*, Nov. 26, 1937, A.M. & D.P.R. 908 (D.P.R., also TRT).

Rhode Is.: on *P. strobus:* Woodville, Nov. 4, 1941, D.P.R. 2008 (D.P.R., also TRT).

Massachusetts: on *Quercus*, Westwood, May 31, 1936, G. D. Darker (D.P.R. 2005, also TRT); on *Fagus*, Goshen, July 2, 1944, A.M. & D.P.R. 2006 (D.P.R., also TRT).

This species was recognized as new independently by the late Prof. H. S. Jackson and Dr. Rogers. It seems to be quite distinct from other described species. However, the problem of an inconstancy of amyloidity presents itself here, as well as the question of the morphological limits of the species, when one encounters a denser-than-usual, more creamy fructification, displaying broader, less tapering cystidia, accompanied by slightly broader spores (D.P.R. 2007). Here it seems to encroach on *P. gracillima*. But the latter is apparently a complex of several ill-defined species; and solution of the problem must await further work on it.

III. PENIOPHORA CALOTHRIX (Pat.) Rog. & Jacks. (Fig. 3)

Corticium calothrix Pat., Cat. Rais. Pl. Cel. Tunisie, p. 59. 1897.

Peniophora pirina Bourd. & Galz. (? subsp. *P. glebulosae* Bres.) Bull. Soc. Mycol. Fr. 28 : 387. [1913].

P. pirina Bourd. & Galz. ex Bourd. & Galz., Hymén. de Fr., p. 290. [1928].

P. delectans Overh., Mycologia, 26 : 513. 1934(!!).

P. calothrix (Pat.) Rog. & Jacks., Farlowia, 1 : 316. 1943.

Fructification white, sometimes somewhat grayish, rarely creamy, thin and delicate to almost cushiony (rarely up to 200 μ in depth), interrupted to

densely reticulate and continuous, broadly effused, with indeterminate margin, pruinose, and hispid; usually easily separable; subicular hyphae comparatively rare or obscure, clamped, 2–2.5(–4.5) μ wide, walls more or less thickened, swelling in KOH and usually dissolving, typically more or less pronouncedly amyloid; hymenium apparently proliferating anew above the husks of old basidia, generally amyloid; cystidia more or less encrusted, 45–75(–125) μ long, (4.5–)5–7.5(–8.5) μ broad just above the branching base, usually narrowing slightly to a neck width of 4–5.5(–7) μ, then most frequently broadening somewhat to an apical width of (4–)4.5–6(–7) μ; lumina capillary, sometimes obliterated toward the base, expanding more or less abrubtly about one-sixth to one-third of the distance from the apex. . .walls amyloid, thick, thinning toward the tip, typically extending somewhat like a hood along one side and over the summit of the otherwise comparatively thin-walled, obtuse head, the walls swelling and dissolving in KOH, the 'hood' often showing a more delayed reaction; basidia with basal walls thickened, typically amyloid, also dissolving or swelling in KOH, (8.5–)11–17.5 × (3.75–)4–5.5 μ, with four more or less erect sterigmata, 3.5–4 μ long; basidiospores cylindric, (4.5–)5–7 × (1.5–)2–3 μ, walls thin, smooth, nonamyloid.

Usually on coniferous wood.

Specimens Examined:

Ontario: on conifer, *Pinus*, *Abies*, or *Picea*: Algonquin Park: Smith L., Sept. 9, 1939, R. F. Cain (TRT 14632); (TRT 14642); Sproule R., Aug. 28, 1939, R.F.C. (TRT 14188); Costello L., Sept. 4, 1939, R.F.C. (TRT 14830); Oxbow L., Aug. 20, 1941, R.F.C. (TRT 23669) **illustrated;** Timagami: Bear Is.: Aug. 1, 1939, R.F.C. (TRT 15252); Aug. 14, 1937, H. S. Jackson (TRT 12746); Spawning L. Portage, Aug. 5, 1938, R.F.C. (TRT 14000); Meadowvale, Peel Co., May 1, 1941, R.F.C. (TRT 17775); Pt. Alexander, Sept. 3, 1941, H.S.J. (TRT 19989).

British Columbia: on bark of *Pseudotsuga taxifolia*, Beaver L., Vancouver Is., June 19, 1948, H.S.J. (TRT 23733).

Massachusetts: on *Pinus strobus*, Purgatory Swamp, Westwood, July 19, 1941, D. P. Rogers 927 (TRT).

Oregon: on coniferous wood, Lorane, Lane Co., Dec. 3, 1938, M. Doty 5235 (TRT).

Pennsylvania: on dead coniferous wood, Cook Forest, Clarion Co., June 23, 1932, L. O. Overholts 16260 (TRT ex type *P. delectans*).

Hawaii: on dicotyledonous wood, Kipapa Gulch, Waipio, Oahu, Oct. 28, 1945, D.P.R. 1891 (TRT).

Latvia: on *Pinus sylvestris*, prov. Vidzeme, May 6, 1934, K. Starcs 1524 (BPI: as *P. pirina*).

P. calothrix is a 'distinctive' species. Characterizing it by the general amyloidity of the thickened walls of cystidia, basidial bases, and hyphae, and the 'hooded' appearance of most cystidia, creates an immediately recognizable picture, calling for unhesitating identification. Unfortunately, such is not

always justified. There are times when hooding is scarcely if at all noticeable, and yet the specimen seems to belong in every other way; or basidial bases and hyphae may not be amyloid, while the cystidia are hooded (as in TRT 13636, identified as *P. propinqua*); or, as appears in a Litschauer collection labelled *P. media* (TRT ex FH-B), these requisites are filled, but the only spores that seem to belong to the specimen are slender cylindric, about 6.5–7 × 1.5 μ. The spore measurements given in the *P. calothrix* description above are intended to indicate a more broadly cylindrical spore, in length two, three, rarely more than three and a half times its width; the narrower spore of the FH-B specimen would seem to bar this collection from the species; and yet, is it defensible to erect a distinct species on so slight a difference? The question of the limits of this species, too, remains unanswered, perhaps to be settled when cultural studies are made.

IV. PENIOPHORA CHAETOPHORA (Hoehn.) Hoehn. & Litsch. (Fig. 8)

Hypochnus chaetophorus Hoehn., K. Akad. Wiss. Wien Math.-Nat. Kl. Sitzber. 111, I : 1007. 1902.

P. chaetophora (Hoehn.) Hoehn. & Litsch., ibid. 116, I: 748. 1907 (!); Bourd. & Galz., Hymén. de Fr., p. 287. [1928](!).

P. dissoluta Overh., Mycologia, 26 : 514. 1934(!!).

Fructification white, grayish, cream, creamy yellow to greenish yellow, usually broadly effused with indeterminate margin. . .thin and delicate to thick and continuous, densely porous reticulate, sometimes as much as 250 μ in depth and cracked, hispid with long cystidia. . .usually easily separable, though sometimes more or less adherent to substratum; subiculum indistinct, of clamped hyphae 1.75–2.5(–3) μ wide, with more or less pronounced walls; cystidia conical, pointed, 60–150–180 μ long, (4.5–)7–10(–12.5) μ broad just above the usually branching base, though some are hypha-like, only 2.75–3 μ wide throughout. . .lumina more or less capillary. . .walls smooth, thickened, in different specimens differing in amyloidity from questionably amyloid to deeply so, very sensitive to KOH, swelling and finally dissolving. . .stem usually more or less entwined with clamped hyphae 2–2.5 μ wide; basidia cylindric, rarely subclavate, often with decumbent base, 10–18 × 3.5–4.5 (–5.5) μ, bearing four slender, more or less arcuate sterigmata, 5–5.5(–7) μ long; basidiospores broadly ellipsoid to cylindric, (4–)5–7(–7.5) × 2.25–3.5 (–4) μ. . .walls thin, smooth, nonamyloid.

On conifer.

Specimens Examined:

Ontario: Timagami: Bear Is.: Aug. 31, 1948, H. S. Jackson (TRT 22549); Aug. 5, 1943, H.S.J. (TRT 20086); Aug. 18, 1944, H.S.J. (TRT 20007); Aug. 13, 1937, H.S.J. (TRT 11951: ver. by Litsch.); Timagami Is.: Aug. 10, 1939, H.S.J. (TRT 15275); Spawning L. Portage: Aug. 11, 1939, H.S.J. (TRT 14966); Cattle Is., Sept. 7, 1935, L. O. Overholts 18709 (TRT 9301); July 24, 1939, H.S.J. (TRT 14924); Ko-ko-ko Bay, Aug. 3,

1939, H.S.J. (TRT 14932); Friday's L., Aug. 12, 1939, H.S.J. (TRT 15037) **illustrated;** Metagama Pt., E. Mainland, Aug. 16, 1937, H.S.J. (TRT 12217); Chalk R.: Pt. Alexander, Sept. 7, 1947, H.S.J. (TRT 22483); Sept. 3, 1941, H.S.J. (TRT 17394); Petawawa For. Res., Sept. 12, 1939, H.S.J. (TRT 14291); Kelso, Halton Co., May 1, 1941, R. F. Cain (TRT 18000); (TRT 18010); Algonquin Park: Oxbow L., Aug. 21, 1941, R.F.C. (TRT 17930); Opeongo L., Sept. 18, 1939, R.F.C. (TRT 14213); Macaulay Rd., Aug. 24, 1939, R.F.C. (TRT 14677); Sturgeon R., Aug. 29, 1944, R.F.C. (TRT 19166); (TRT 19184); (TRT 20102); Credit Forks, Apr. 27, 1941, R.F.C. (TRT 17007); Aurora, York Co., Sept. 29, 1945, H.S.J. (TRT 21839); Maple, Aug. 31, 1939, H.S.J. (TRT 16620); (TRT 17707); Nov. 22, 1941, H.S.J. (TRT 17781).

British Columbia: Mt. Douglas Park, Vancouver Is., July 2, 1948, H.S.J. (TRT 23863).

California: Squaw Valley Creek, Mt. Shasta, Siskiyou Co., July 10, 1947, Wm. Bridge Cooke 20275 (TRT).

Massachusetts: Petersham, Aug. 18, 1938, J. R. Hansbrough, BPI F.P.-84078 (TRT).

Oregon: Heceta Beach, Nov. 26, 1937, A.M. & D.P. Rogers 449 (TRT).

Pennsylvania: Musser Gap, Center Co., Apr. 23, 1933, W. L. White & C. Bidwell, Overh. 16264 (TRT: ex type *P. dissoluta*).

Austria: Gnadenwald near Hall in Tirol, July 20, 1914, V. Litschauer, Romell Herb. (S).

France: L'Hospitalet, Aveyron: May, 1911, Galzin 9238, Bourd. 7989, Lloyd 33871 (BPI); June 2, 1914, Galz., Bourd., Bres. (BPI).

The cystidia of this species are so large and firm, that the pronouncedly hispid appearance of the fructification under the lens is often characteristic enough to indicate its identity, though microscopic study of basidia and spores as well as cystidia is necessary for assured distinction between *P. chaetophora* and *P. vermifera*. Bourdot and Galzin's description of *P. abnormis* (1) suggests that it may be very close to *P. chaetophora*; but I have had to leave the former out of consideration here, having been unable to secure any material of that species.

V. PENIOPHORA CRASSA Burt ex Peck (Fig. 2)

Stereum Karstenii Bres., I. R. Accad. Agiati Atti III, 3 : 108. 1897; Bourd. & Galz., Bull. Soc. Mycol. Fr. 37 : 126. 1921; Hymén. de Fr., p. 385. [1928] (not *P. Karstenii* Mass., J. Linn. Soc. Botan. 25 : 153. 1889).

P. crassa Burt ex Peck, N.Y. State Mus. Rept. 54 : 155. 1901; Missouri Botan. Garden Ann. 12 : 286. [1926]; Wakefield, Trans. Br. Mycol. Soc. 35 : 58. 1952.

Lloydella Karstenii (Bres.) Hoehn. & Litsch., K. Akad. Wiss. Wien, Math.-Nat. Kl., Sitzber. 115, I : 1568. 1906.

P. verticillata Burt, Missouri Botan. Garden Ann. 12 : 285. [1926].

Stereum Karstenii fa. *incrustata* Pilat, Bull. Soc. Mycol. Fr. 49 : 44. 1933.

Fructification starting as discrete, pin-point, fleshy patches, becoming confluent and widespread, often indurated, attaining a depth up to 1 mm. or more. . .hymenium cream to yellow-buff, coral, cinnamon, or darker, frequently deeply fissured, exposing the cream to white subiculum, margin determinate, white, fibrous, sometimes reflexed, surface pruinose, velvety or, on occasion, almost tomentose under the lens; more or less separable; subicular layer fairly loose, mainly of prominently clamped hyphae about 4 μ wide, walls thickened and soluble in KOH; hymenium often zonate, composed of vertically arranged, often prominently clamped hyphae, 1.5–2–3 μ broad, thin- but usually firm-walled, along with broader (5 μ wide) thick-walled hyphae, perhaps cystidiophores or cystidial stems. . .frequently with massed crystals scattered throughout; cystidia not always clear, sometimes completely embedded, otherwise projecting 15–30–70(–over 100) μ, very long, with basal septa hard to find. . .usually more or less obovate, with thick stem walls, nonamyloid, dissolving in KOH. . .lumina expanding more or less gradually toward obtuse apices, these usually 4–10 μ broad, sometimes heavily encrusted, thin-walled or sometimes with rather thickened walls best differentiated in Melzer's; cystidial stems frequently very slender, 2.5 μ broad 30 μ from apex, at other times as much as 7 μ broad a distance of 100 μ from apex, with variations between and beyond; basidia very slender, rising above the hymenial surface when mature, broadening below the apex to a width of 2.5–3.5 μ, their length rarely determinable with any accuracy because the basal septa are obscured; basidiospores allantoid, often narrowed toward the apicular end, (4–)4.5–6(–8.5) $\times$ (1–)1.25–2(–2.5) μ. . . walls thin, smooth, nonamyloid.

On conifer only—*Abies*, *Pinus*, *Picea*, *Pseudotsuga*, *Thuja*, and *Tsuga*.

Specimens Examined:

Ontario: Sturgeon R., Aug. 30, 1944, R. F. Cain (TRT 19156) **illustrated;** Timagami: Bear Is., Aug. 31, 1948, H. S. Jackson (TRT 22561); Aug 12, 1943, H.S.J. (TRT 20012); Sept. 3, 1937, H.S.J. (TRT 12141); Aug. 9, 1937, H.S.J. (TRT 11946); Sept. 1, 1937, H.S.J. (TRT 16735); Aug. 13, 1937, H.S.J. (TRT 16756); Aug. 19, 1939, H.S.J. (TRT 16277); Aug. 23, 1946, H.S.J. (TRT 21036); Aug. 19, 1939, H.S.J. (TRT 15003); Aug. 9, 1937, H.S.J. (TRT 12630); Sept. 7, 1935, H.S.J. (TRT 8789); Sept. 1, 1937, A. J. Skolko (TRT 12489); Aug. 28, 1935, R.F.C. (TRT 8770); Sept. 4, 1935, R. Biggs 457 (TRT 8256); Sept. 3, 1935, R.B. 450 (TRT 8258); Paradis Bay, Aug. 18, 1939, H.S.J. (TRT 16296); Friday's L.; Aug. 12, 1939, H.S.J. (TRT 14949); (TRT 14973); Long Sand Pt.: Aug. 24, 1937, H.S.J. (TRT 12223); (TRT 11926); July 24, 1939, H.S.J. (TRT 14926); Gull L.P., Sept. 9, 1936, R.B. (TRT 9745); Sept. 9, 1935, R.B. (TRT 8737); Aug. 23, 1935, R.B. 422 (TRT 8257); Algonquin Park: Sept. 17, 1939, H.S.J. (TRT 14279); (TRT 14512); Petawawa For. Res., Sept. 12, 1939, H.S.J. (TRT 14393); Toronto, Sept. 1908, Thos. Langton 23, Lloyd 51810 (TRT).

British Columbia: Cowichan L. June 9, 1948, W. G. Ziller, V 3157* (TRT); May 15, 1948, W.G.Z., V 2776 (TRT); Sept. 9, 1941, J. E. Bier 85 (TRT); Cathedral Grove, May 25, 1948, A. W. Porter, V 2822 (TRT); Makinson's Flats, June 24, 1947, P. J. Salisbury, V 2670, DAOM 17598 (TRT); E. Saanich Rd., Sept. 7, 1938, I. Mounce, DAOM F-9001 (TRT); Daisy L., June 22, 1930, J. S. Mielke, Over. 13970 (TRT).

Nova Scotia: Victoria Park, Truro, Aug. 20, 1935, L. E. Wehmeyer 1797 (TRT).

North Carolina: Ashville, Nov. 6, 1949, Hepboy & Toole, BPI F.P.-90477 (TRT); Aug. 25, 1950, Josiah L. Lowe 4449 (TRT).

California: Trinidad, May 1931, H. E. Parks 3691, UC 491 (TRT); Mt. Shasta, Siskiyou Co., Apr. 7, 1947, Wm. Bridge Cooke 19286 (TRT).

Idaho: Priest R., Sept. 1915, J. R. Weir, Overh. 3521 (TRT); Sept. 4, 1915, J.R.W. 9, J. A. Stevenson Herb. (NY); Upper Priest R., Aug. 25, 1925, C. R. Stillinger, Overh. 9956 (TRT); Beville, June 10, 1921, J.R.W. 20038 (NY).

Maine: Lyman, Sept. 14, 1926, P. Spaulding, BPI F.P.-16948 (TRT).

Massachusetts: Sharon, Oct. 1922, A.P.D. Piquet, FH (NY).

Montana: Echo L., July 8, 1928, C. H. Kauffman, MICH 74 (TRT).

New York: Enfield Gorge, Oct. 19, 1901, G. F. Atkinson 8008 (TRT).

Oregon: Mt. Hood Nat. For., Apr. 9, 1941, G. H. Englerth, BPI F.P.-91379 (TRT); April 11, 1941, G.H.E. *et al.* BPI F.P.-91378 (TRT); Seaside, Apr. 26, 1940, G.H.E., BPI F.P.-91347 (TRT); Takilma, Siskiyou, Nov. 27, 1925, C. A. Brown, MICH 75 (TRT).

Pennsylvania: Little Shingletown Valley, Jan. 24, 1934, A. P. Kelley and Lawrence White, White 1288 (TRT).

Tennessee: Cades Cove, Mar. 11, 1945, L. R. Hesler, TENN 16742 (TRT).

Vermont: Ripton, Mar. 6, 1899, E. A. Burt, Atkinson coll., Burt Herb. (TRT 23741).

Washington: Spokane Co., Sept. 11, 1950, W. B. & V. G. Cooke 27927 (TRT); Quilcene, May 16, 1940, G.H.E. *et al.*, BPI F.P.-91350 (TRT).

This species has been called 'very distinctive'; i.e. certain of its characteristics are so pointedly different from those of other species judged to be in the same group that one is tempted to identify the specimen, without looking any further, on the basis of the following features: vertical arrangement of long lines of hyphae and extremely elongated though variable cystidia, very narrow basidia, slender spores, and a zonate, dense fruiting body. So far, we have little cause to question this delimitation. Burt (loc. cit.) distinguished between *P. crassa* and *P. verticillata* on the basis of presence or absence of crystals; but as noted by Rogers and Jackson (9), this is hardly feasible. However, it will not surprise me to find that culturing may provide significant enough differences for segregation on other counts. Meanwhile, we leave *P. crassa* as a unit species characterized as above.

* *V numbers are from the Laboratory of Forest Biology, Unit of Forest Pathology, Victoria, B.C.*

The question of whether or not *P. crassa* belongs in this group need not be dealt with at this time, since the whole section is not covered here. If this species is a *Peniophora* (see Rogers and Jackson (9)), it seems to be closer to the *Tubuliferae* than to other sections of the genus. For the time being, this fact must suffice to place it here.

VI. PENIOPHORA JUNIPERINA Bourd. & Galz. ex Bourd. & Galz. (Fig. 4)

P. juniperina nov. subsp. under *P. glebulosa* Bres., Bourd. & Galz., Bull. Soc. Mycol. Fr. 28 : 386. [1913].

P. juniperina Bourd. & Galz. ex Bourd. & Galz. Hymén. de Fr., p. 289. [1928].

Fructification usually white, sometimes grayish or creamy, most often broadly effused with indeterminate margin. . .ranging from thin, delicate, more or less interrupted and somewhat pruinose, to densely continuous, cracked, sometimes almost membranous. . . usually smooth, though occasionally sparsely and minutely odontioid. . . closely adherent or more or less separable; subiculum often appreciable in depth, composed mainly of indistinct hyphae, clamped, 2–2.5–2.75 μ wide, sometimes with somewhat thickened walls which dissolve in KOH; cystidia 50–75–95 μ long, (3.5–)5.5–7.5(–9) μ broad near the base, stem narrowing to a neck width of 3–5(–5.5) μ, where the capillary lumen expands more or less abruptly to form thin-walled apical bulbs (5–)7–10(–11) × (6–)7–9(–11.5) μ. . .stem walls varying in amyloidity in different collections and occasionally in the same specimen, from nonamyloid to questionably to positively so, thick, smooth, dissolving in KOH. . .apices sometimes heavily massed with crystals; basidia cylindric to subclavate, 7–8.5–15(–18) × 3.5–4.25(–5) μ. . .basal walls sometimes pronounced, more or less soluble in KOH; basidiospores slender–cylindric, where very slender almost allantoid, where broader scarcely curved, (4–)4.75–7.25(–8.5) × (0.75–)1.0–1.5–2(–2.5) μ. . .walls thin, smooth, nonamyloid.
On coniferous wood.

Specimens Examined:

Ontario: Bear Is., Timagami, July 25, 1936, R. Biggs 951 (TRT 9517); Sproule R., Algonquin Park, Aug. 28, 1939, R. F. Cain (TRT 14190) **illustrated;** Sunnybrook Park, Toronto, Sept. 23, 1944, H. S. Jackson (TRT 20024).

British Columbia: Vancouver Is.: L. Cowichan, June 22, 1948, H. S. J. (TRT 23744); between Sooke & Jordan R., July 3, 1948, H. S. J. (TRT 23742); Saanichton woods, Nov. 27, 1940, I. Mounce, DAOM F-10135 (TRT).

Idaho: Bonner Co., July 2, 1940, A. W. Slipp 745, ID 2445 (TRT).

Massachusetts: Blue Hill, Canton, Nov. 30, 1935, D. P. Rogers 6 (TRT).

Oregon: S. of Yachats, Nov. 26, 1937, A.M. & D.P.R. 721 (TRT).

France: St. Priest, Allier, Nov. 1913, Bourdot 12272, FH (TRT); Aveyron, July 4, 1911, Galz. 9546, Bourd. 8040, Lloyd 44575 (BPI).

Sweden: Upl. 'Erken', n. of Rimbo, Nov. 3, 1918, Lars. Romell 4303 (S) (det. V. Litsch.).

Bourdot and Galzin's statement regarding this species (1), "plus variable que *P. accedens*," finds ready confirmation in examination of the specimens cited. There is variation in the gross appearance of the fructifications, in the breadth of the cystidia and the prominence of their bulbs, in the amyloidity of of cystidial walls, in the slenderness and amount of curvature of the spores. I have not attempted to sort the specimens into Bourdot's varieties, because the distinctions do not appear to be clear enough. For example: the most clear-cut variety-delineating character is that of a near-odontioid fructification, assigned by Bourdot to the variety *papillata;* of those cited above, only the Swedish specimen shows this characteristic, and yet Litschauer identified it as the variety *communis*. It seems to me that at this point in our knowledge of the group, recognition to the species level should satisfy us.

VII. **Peniophora sceptrifera** Jacks. & Were. n. sp. (sceptrum fero (L): scepter-bearing) (Fig. 5)

Diagnosis Typi:

Fructificatio alba, delicata, interrupta, effusa, ad substratum arcte adnata; subiculo parco, praesertim e hyphis nodoso-septatis, horizontalibus 1.5–2 μ latis; cystidiis valde subtilibus, 35–65 μ longis, prope basin 1.5–2.5 μ latis, ad isthmum 1.25–1.75 μ latum acriter attenuatis, super quem luminibus in bulbum prominente tenuiter tunicatum dilatatis, 4–7 $\times$ 4–5 μ; tunicae cystidiorum non amyloideae, glaberrimae, in KOH dilutae; basidia clavata e plus minusve flexuosis caulibus, 10–18 $\times$ 4–5.5 μ; sterigmata exilia, divergentia, arcuata, ca. ad 4 μ longa; sporae late ellipticae, apiculatae, illarum tunicis tenuibus, glabris, non amyloideis, 5–6.5 $\times$ 3–4.5 μ.

Description of Species:

Fructification white, of hoar frost delicacy, effused, closely adnate to substratum; subiculum scanty, mainly of horizontal, clamped hyphae, 1.5–2 μ wide; cystidia very slender, 35–75 μ long, 1.5–3 μ wide near the base, tapering sharply to a neck width of 1.0–1.75 μ, above which the lumen flares into prominent thin-walled bulbs, 4–7 $\times$ 4–5(–6.5) μ. . .walls nonamyloid, pronounced, smooth, dissolving in KOH; basidia clavate, often on more or less flexuous stems, 10–18 $\times$ 4–5.5 μ, usually solitary, arising perpendicular to horizontal hyphae. . .sterigmata slim, divergent, arcuate, up to about 4 μ long; basidiospores broadly ellipsoid, sometimes almost subglobose, (4.0–)5–6.5 $\times$ 3–4.5 μ, flattened on one side, apiculate. . .walls thin, smooth, nonamyloid. On leafy liverwort and conifer.

Specimens Examined:

Ontario: on leafy liverwort on rotten conifer log, Cache L., Algonquin Park, Sept 1, 1939, R. F. Cain (TRT 14794) TYPE; on conifer: Brant Co., Aug. 4, 1941, R.F.C. (TRT 18024); Bear Is., L. Timagami, Aug. 7, 1943, H. S. Jackson (TRT 20061).

This species was recognized as new by the late Prof. H. S. Jackson, and turned over to me for description.

In this group, four species have been described as having cystidia with prominent apical bulbs. . .*P. accedens*, whose cystidial stems are subcylindric, narrowing only slightly to the neck, and whose spores are broadly subcylindric; *P. juniperina*, its stems broader, usually narrowing more pronouncedly, its spores slender cylindric, often allantoid; *P. regifica* with cystidia like those of the latter species, but generally larger, with spores broadly ellipsoid; and *P. sceptrifera*, its cystidia very slender and narrowing to capillarity at the neck, spores broadly ellipsoid but smaller than those of the latter. These four species are clearly distinguishable from each other.

VIII. PENIOPHORA VERMIFERA Bourd. (Fig. 9)

P. vermifera Bourd. Rev. Sc. du Bourb. 23 : 11. 1910; Bourd. & Galz., Bull. Soc. Mycol. Fr. 28 : 384. [1913]; Hymén. de Fr., p. 285. [1928].

Fructification maculiform to widely effused, creamy yellow, dense, usually though not always cracking on drying, more or less separable from substratum. . .thin, though sometimes attaining a depth up to 100 or 200 μ; margin more or less clearly defined; subicular hyphae indistinct, perhaps agglutinated, apparently frequently clamped, some with thickened walls dissolving in KOH, others thin-walled, 2–2.25 μ wide; cystidia conical, 75–100–185 μ long, 10–25 μ broad just above the rooting base, narrowing to more or less pointed apices, typically sheathed in dendroid branching hyphae 0.75–1.5 μ broad, sometimes also encrusted. . .walls lightly but positively amyloid, thick, 3.5–5.5–7 μ wide, dissolving in KOH, though apices and outer layer of wall often left standing after KOH action. . .lumina usually fairly broad at base, frequently becoming capillary well below the middle, often completely obscured apically, though sometimes not narrowing to capillarity even at the tip; basidia sinuately clavate, 20–45 $\times$ (5–7–)8.5–11.5 μ, with usually four fleshy, divergently arcuate sterigmata 6.5–7.5 μ long, 2.5 μ broad basally; basidiospores flexuous-navicular, usually somewhat pointed toward the distal end, (10–)15–25(–30) $\times$ (3–3.5–)4–5.5 μ. . .walls thin, smooth, nonamyloid. On dicotyledonous wood.

Specimens Examined:

British Columbia: on *Osmaronia cerasiformis*, Gillespie Rd., Vancouver Is., July 28, 1948, H. S. Jackson (TRT 23711) **illustrated;** on *Vaccinium:* L. Cowichan For. Exptl. Sta., June 23, 1948, H.S.J. (TRT 23712); (TRT 23713).

California: on *Gaultheria shallon*, Spruce Cove, Trinidad, Mar. 27, 1947, H. E. Parks 7028 (TRT); Apr. 1947, H.E.P. 7059 (TRT).

Hawaii: Waikane, Oahu, Mar. 23, 1947, D. P. Rogers 1961 (TRT).

France: on *Erica arborea*, Guergues près St. Sernin, Aveyron, Apr. 9, 1910, A. Galzin, Bourd. 7130 (NY, S. and TRT); July 3, 1909, A.G. 4200, Bourd. 7962, Lloyd 38022 (BPI).

Bourdot and Galzin (1) place *P. vermifera* in subsection ** of the *Tubuliferae*, characterized by rough-walled cystidia. But in this species, the roughened appearance proves to be due to dendroid hyphae in which the cystidia are sheathed, the walls themselves being as smooth as those of any member of subsection ***. In addition, these walls dissolve in KOH. Whether or not this character is sufficiently significant to be used to segregate the species possessing it from other members of the genus remains to be discussed at a later date, when cultural studies and perhaps cell wall analyses have provided evidence pro or con. Meanwhile, *P. vermifera* is left in this section, with the pointed notation that its basidia and spores are strikingly different from those of other species of the *Tubuliferae*.

It is interesting to observe, here, that there is another species known whose cystidia are sheathed, like those of *P. vermifera*, in dendroid hyphae. Patouillard (8) named it *Epithele dussii*, thinking that the cystidia were fascicles of hyphae; Hoehnel and Litschauer (5) recognized the cystidial character of the 'fascicles' and renamed the species *Peniophora dussii*, but described the spores as differing from those observed by Patouillard. On examining the NY portion of the Patouillard type collection (C. Duss, 1899), I was unable to find any spores or basidia, and noted that the thickened walls of the cystidia were brittle but insoluble in KOH. Yet, in a collection from Colombia (TRT: G. W. Martin 3657), the cystidial walls are soluble in KOH, and the spores close to those described by Patouillard and later by Burt (2). Examination of the Berlin collections studied by Hoehnel and Litschauer may solve the problem of "*Epithele dussii*".

Note re nomenclature: In both the Bull. Soc. Mycol. Fr. [1913], and Hymén. de Fr. [1928], Bourdot and Galzin gave binary names to subspecies, usually indicating the rank by using slanted letters for subspecies, erect letters for species. Since, according to the Rules (Art. 34), "the use of a binary nomenclature for subdivisions of species is not admissible", only the legitimate usage of the binary name is recognized herein; hence we have: *P. accedens* Bourd. & Galz. ex Wakef. & Pears., *P. juniperina* Bourd. & Galz. ex Bourd. & Galz., etc.

Acknowledgments

Financial support for this work was provided by the National Research Council of Canada, as a grant to the late Prof. H. S. Jackson, whose project it was, and was used by the writer in her capacity as technical assistant to

Dr. Jackson while she was a graduate student at the University of Toronto. The writer is indebted for invaluable direction and assistance to the late Dr. Jackson, to Dr. R. F. Cain, and Dr. D. P. Rogers; for the entire foundation of this effort to Miss E. Ruth Dearden; for Latin descriptions to Mr. Leslie A. Garay; for information regarding, and permission to publish the description of *P. angusta*, to Dr. Rogers; and for the loan of critical material to Dr. G. Haglund, Naturhistoriska Riksmuseet, Stockholm, Dr. D. P. Rogers of the N.Y. Botanical Garden, and Mr. J. A. Stevenson, Bureau of Plant Industry, U.S.D.A. Material kindly supplied by Mr. J. Eriksson of Uppsala, Sweden, and more of that sent by Dr. Haglund will be considered at a later date.

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Explanation of Figures

Fig. 1. Diagram of typical cystidium, explaining descriptive terms used.
Fig. 2. *Peniophora crassa.*
Fig. 3. *Peniophora calothrix.*

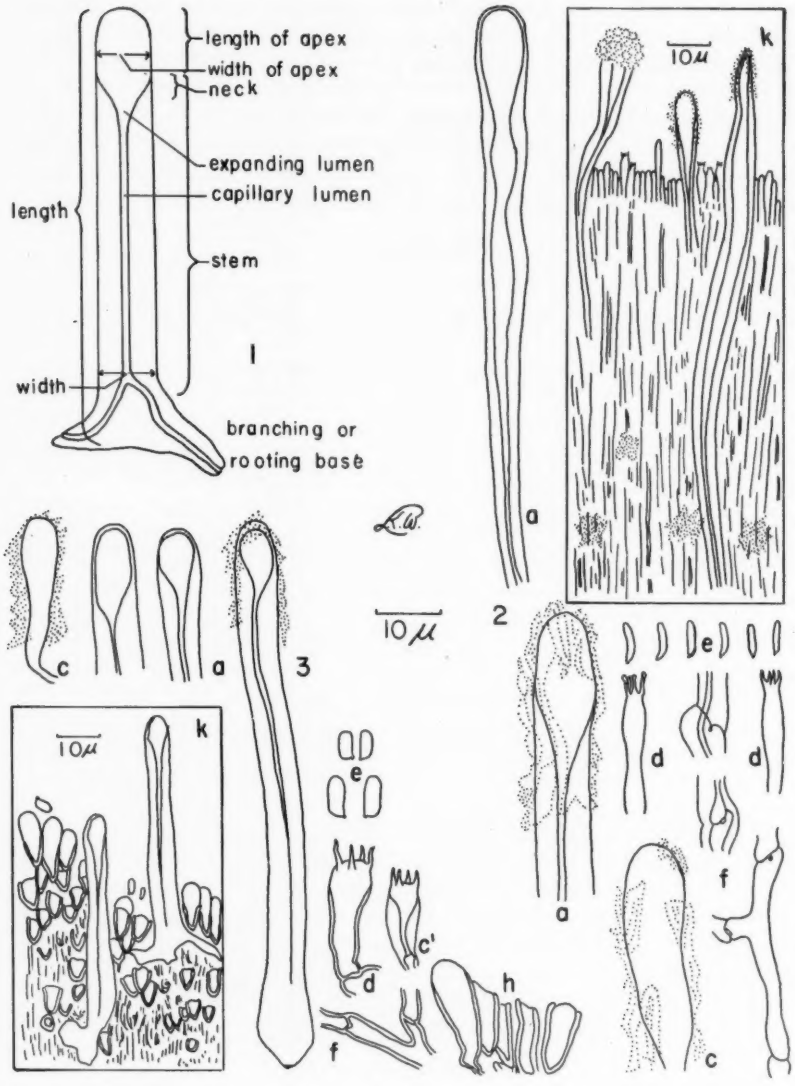
Fig. 4. *Peniophora juniperina.*
Fig. 5. *Peniophora sceptrifera.*
Fig. 6. *Peniophora accedens.*
Fig. 7. *Peniophora angusta.*

Fig. 8. *Peniophora chaetophora.*
Fig. 9. *Peniophora vermifera.*

(*a*) Mature cystidia
(*b*) Young cystidia
(*c*) Cystidium after action of KOH
(*c'*) Basidium after action of KOH (Fig. 3)
(*d*) Basidia
(*e*) Basidiospores
(*f*) General hyphae
(*g*) Climbing hyphae (Fig. 8 and 9)
(*h*) Basidial bases (Fig. 3)
(*k*) Hymenium

All drawings except *k* drawn at approximately 1500 magnifications (*k* at approx. 1000×) and reproduced at a magnification of approximately 1000× (*k* at approx. 650×).

(Note: Figs. 1 to 9 follow.)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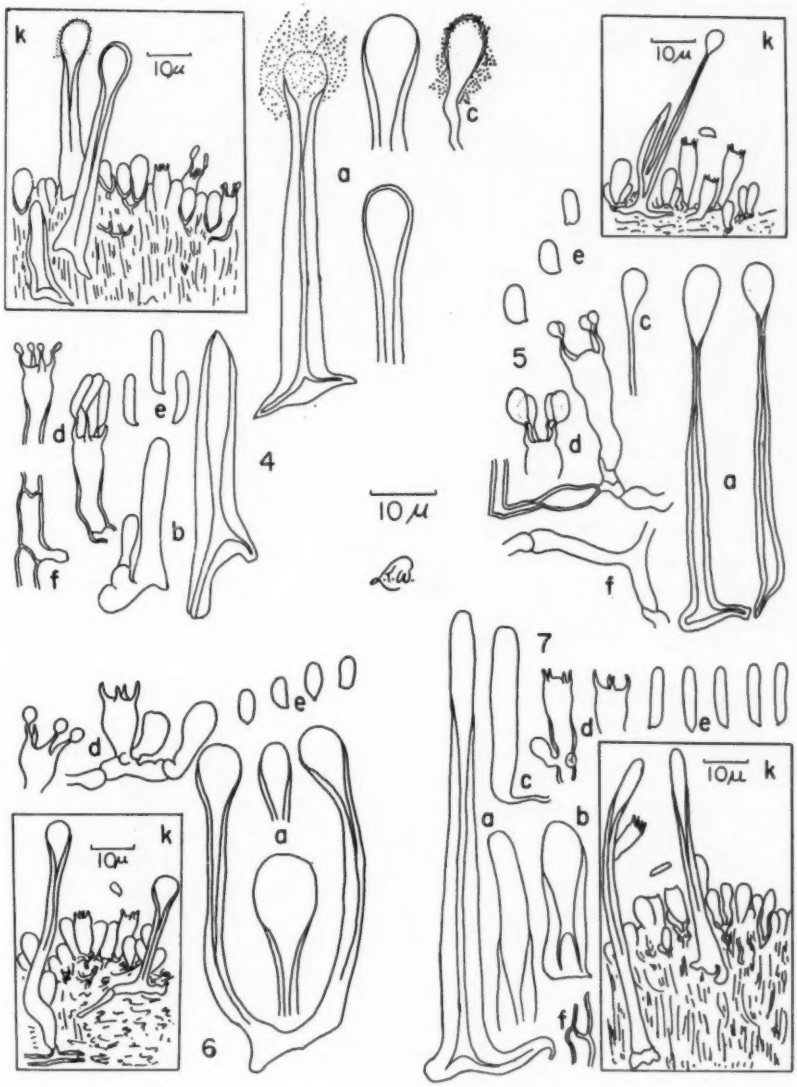
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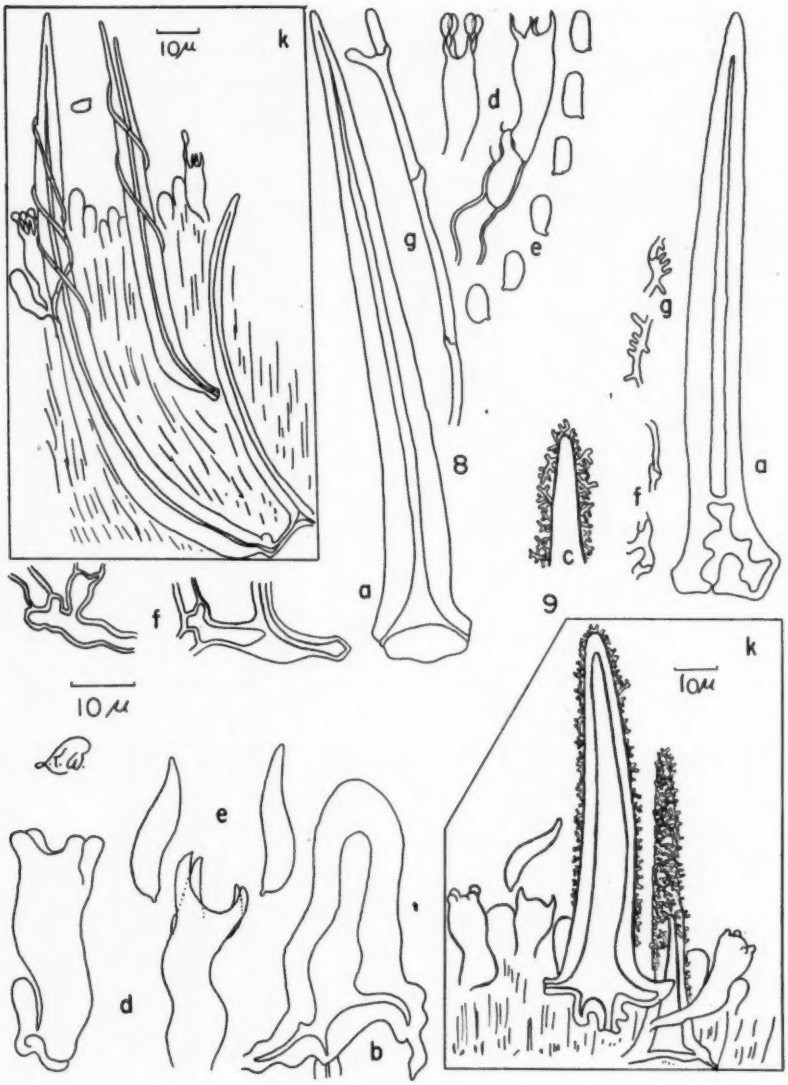
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NOTES ON SEED-BORNE FUNGI

VII. *CHAETOMIUM*[1]

By A. J. Skolko and J. W. Groves[2]

Abstract

In a previous paper, the species of the genus *Chaetomium* possessing dichotomously branched terminal hairs were described and figured. In the present report the remaining species of the genus are considered with special emphasis on the species isolated from seeds. Of a total of 47 recognized species, 16 have been found inhabiting seeds; one of these, *C. atrosporum* is described as new. Type collections of many of the species have been examined and descriptions and illustrations of these are included, along with a key to the recognized species.

The Genus *Chaetomium*

In the preceding paper of this series on seed-borne fungi (10), the species of *Chaetomium* possessing dichotomously branched perithecial hairs were described and illustrated. Six of the eight recognized species in that group have been isolated from seeds of agricultural crops following the procedure outlined in the first paper of the series (6), two of the species being described as new. Recently an additional species with dichotomous hairs was described by La Touche (7) and it has been included in the present paper although it has not been isolated from seed.

The remaining species of the genus isolated from germinating seeds are described and figured here. In addition, species other than those isolated from seed are included and frequently it has been possible to examine type or authentic specimens. Some of these species possess branched terminal hairs, but they are either inconspicuously branched or not truly dichotomously branched.

In 1915 Chivers (4) monographed the genus and retained 28 species as valid. Since that date about 30 new species have been described some of which have already been invalidated through synonymy. It is probable that about 50 species will survive and new species undoubtedly will be added. The possible variation in type of perithecial hairs, spores, and other perithecial characters seems to be almost unlimited.

In his key to the genus, Chivers (4) utilized the branched character of the perithecial hairs as a major point of separation. The wisdom of this selection is open to question because the branching in some species is very inconspicuous or even rare and it is extremely difficult to determine whether the hairs are branched or unbranched. Equally questionable is the diagnostic emphasis sometimes placed upon such variable characters as coloration of the substratum or medium upon which the fungus may be growing, the rhizoidal attachment of the perithecium, which is probably influenced by the consistency of the substratum, and the incrustation of the hairs which seems to be a

[1] *Manuscript received July 9, 1953.*
Contribution No. 1288 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.
[2] *Senior Plant Pathologist and Principal Mycologist, respectively.*

character that develops with age and which may dissolve in the mounting medium. Similarly, the extrusion of the spores through the ostiole as cirrhi or as an irregular mass may be influenced by the existing conditions. It is suggested that the shape and size of the perithecia, conspicuous characters of the hairs, and the shape and size of the spores provide a more practical basis for species separation and these characters have been used in the artificial key to the genus presented below. At the same time, it is felt that similarities in these characters to some extent indicate natural relationships. The character of the ostiole is considered of fundamental diagnostic importance in other genera, but in the genus *Chaetomium* it may vary from a simple, narrow to wide opening, to one that is beaked or provided with a long neck and modified ostiolar cells. In most species the ascus is club-shaped but in a few the ascus is cylindrical and the spores monostichous in arrangement. In all species the asci are evanescent.

In the descriptions that follow, reference is made to "plant" characters. This term is used in description of the macroscopic characters of the specimen as seen under low magnification by reflected light, including perithecia, hairs, mycelium, and extruded spore mass. Cultures were grown on 2% malt extract agar. Description of spore shape and size has been made for fully mature spores viewed in the largest dimensions or face view rather than in edge view. Microscopic mounts were made in lactophenol and then heated gently to ensure that the spores would become fully expanded. Synonymy of species, published after 1915 only, is listed. For earlier synonymy, Chivers' (4) monograph should be consulted. Isolations of *Chaetomium* spp. in the present study have been mainly derived from seed of vegetable and certain field crops. Very few cereal crop seeds have been examined and it is likely that many more species could be found on and in them.

Key to the Species of *Chaetomium*

1. Perithecium ovoid, globose, or subglobose 2
1. Perithecium elongate, barrel-shaped, vase-shaped, or cylindric 32
2. Terminal hairs dichotomously branched 3
2. Terminal hairs straight, with or without side branches 10
2. Terminal hairs flexed or long undulate, with or without recurved or branched tips 13
2. Terminal hairs arcuate, with recurved or coiled tips 17
2. Terminal hairs sinuous or loosely coiled 18
2. Terminal hairs regularly spirally coiled, may be straight below 20
2. Terminal hairs in reversed loops or coils 30

Terminal Hairs Dichotomously Branched

3. Branches of terminal hairs with essentially straight internodes 4
3. Branches of terminal hairs and internodes distinctly incurved or reflexed 9
4. Unbranched terminal hairs present at maturity in addition to dichotomously branched hairs, conspicuous, usually projecting beyond the mass of branched hairs 5
4. Unbranched terminal hairs absent at maturity but may be present in younger stages 7
5. Perithecium large, up to 450μ wide; terminal hairs coarsely roughened, stout, 5-8μ wide; spores lemon-shaped, dark-colored, large, 10-11 $\times$ 7-8μ ..... *C. elatum*
5. Perithecium medium size, 370μ wide; branches of terminal hairs anastomosing; spores elliptical or spindle-shaped, 10-12 $\times$ 7-9μ ..... *C. cuniculorum*
5. Perithecium small, not exceeding 200μ in width; spores oval to ovoid, less than 7μ long 6

6. Branched terminal hairs smooth or slightly roughened, branches few with long internodes, widespreading and sometimes slightly reflexed; unbranched terminal hairs graceful, long-projecting, tapering gradually to a long tip. . *C. dolichotrichum*
6. Branched terminal hairs coarse, often with rough projections, branches at acute angle and with short internodes; unbranched terminal hairs rigid with rapidly tapering tip, projecting only a short distance beyond the mass of branched hairs. . . . . *C. funicola*
7. Terminal hairs unequally thickened and constricted, with minute granules; spores broadly ovoid, flattened on one side, strongly umbonate at one end, 6.5-8.5μ wide. . . . . *C. thermophile*
7. Terminal hairs uniform, not constricted; spores oval, not conspicuously umbonate nor apiculate, 4.5-5.5μ wide. 8
8. Perithecium up to 200μ wide; terminal hairs repeatedly and regularly branched forming a close network, hairs roughened by numerous blunt projections. . . . . *C. indicum*
8. Perithecium not more than 140μ wide; terminal hairs rigid with only a few short branches near the top, internodes short, hairs smooth with few sharp projections at the blunt hyaline tip. . . . . *C. erectum*
9. Terminal hairs straight with incurved branches, producing characteristic "crab-claw" effect; perithecium 175μ wide. . . . . *C. cancroideum*
9. Terminal hairs arcuate with branches strongly reflexed; perithecium not over 125μ wide. . . . . *C. reflexum*

Terminal Hairs Straight, With or Without Side Branches

10. Terminal hairs branched, broad, 5-7μ wide at base. 11
10. Terminal hairs branched or unbranched, slender, usually not over 4μ wide at base. 12
11. Terminal hairs rigid, spinelike, tapering, dark-colored, with rough projections below, side branches in upper portion, rebranching at right angles; spores ovoid. . . . . *C. spinosum*
11. Terminal hairs broad, untapered, smooth, with short irregular branches or coils at the tips; spores ellipsoid. . . . . *C. cristatum*
12. Perithecium large, up to 250μ wide, beaked; spores triangular; terminal hairs unbranched. . . . . *C. trigonosporum*
12. Perithecium small, up to 100μ wide, beaked, vase-shaped; spores globose-ovoid; terminal hairs unbranched. . . . . *C. seminudum*
12. Perithecium small, up to 120μ wide, not beaked; hairs extremely long, flexed; spores ellipsoid; terminal hairs branched at wide angle. . . . . *C. atrobrunneum*

Terminal Hairs Flexed to Long Undulate

13. Terminal hairs with recurved or circinate tips; spores ellipsoid-fusiform. 14
13. Terminal hairs with simple or branched tips; spores subglobose to ellipsoid. 15
14. Terminal hairs with open, recurved tips. . . . . *C. murorum*
14. Terminal hairs with circinate, two to three times recurved tips. . . . *C. circinatum*
15. Terminal hairs with branched tips; ostiole with distinct collar; spores subglobose to ovoid. . . . . *C. causiaeformis*
15. Terminal hairs with simple tips. 16
16. Spores lemon-shaped, 9-12.5 × 7.5-9.0μ; hairs 4μ wide. . . . . *C. olivaceum*
16. Spores lemon-shaped, 8.0-9.5 × 6.0-8.0μ; hairs 3μ wide. . . . . *C. globosum*
16. Spores ellipsoid, faintly umbonate at both ends. . . . . *C. atrobrunneum*

Terminal Hairs Arcuate

17. Terminal hairs incurved at tips; spores ellipsoid-flattened. . . . . *C. aureum*
17. Terminal hairs inflated, once-recurved at tips; spores lemon-shaped. *C. turgidopilosum*
17. Terminal hairs incurved or once-recurved at tips; spores fusiform. . . . . *C. fusiforme*
17. Terminal hairs coiled at tips; spores ovoid, flattened on one side. . . . . *C. trilaterale*

Terminal Hairs Sinuous to Loosely Coiled

18. Spores ellipsoid. . . . . *C. succineum*
18. Spores subglobose, large, dark-colored, with two pores. . . . . *C. atrosporum*
18. Spores lemon-shaped. 19
19. Terminal hairs extremely fine, 1.5-2.0μ wide, unbranched, interwoven into a dense mass. . . . . *C. ochraceum*

19. Terminal hairs about 3μ wide, loosely coiled, with few branches..... *C. globosum*
19. Terminal hairs about 3μ wide, irregularly waved or coiled, with several branches; perithecium narrowed above..... *C. sphaerale*

Terminal Hairs Spirally Coiled

20. Terminal hairs with eight or less coils..... 21
20. Terminal hairs with more than eight coils..... 27
21. Spores angular..... 22
21. Spores not angular..... 23
22. Spores square 5.5-6.5 × 5.0-6.0μ; terminal hairs irregularly coiled, with coiled branches of equal width to hairs..... *C. quadrangulatum*
22. Spores lemon-shaped, 10.0-14.0 × 7.0-9.0μ, somewhat variable in shape but strongly umbonate at both ends to give angular shape; terminal hairs irregularly coiled, with coiled branches narrower than hairs..... *C. tetrasporum*
23. Spores ovoid-ellipsoid to ellipsoid..... 24
23. Spores broadly ovoid or lemon-shaped..... 25
24. Terminal hairs broad, straight, untapered, with short, irregular branches or coils at tip; spores ellipsoid, 8-12 × 4.5-6μ..... *C. cristatum*
24. Terminal hairs slender, less than 5μ wide, straight below, spirally coiled above; spores broadly ellipsoid, 10-13 × 7-8.5μ..... *C. gangligerum*
25. Terminal hairs slender, less than 5μ wide; spores obscurely apiculate or rounded, 7.0-8.5 × 6-7μ; ostiolar collar present..... *C. bostrychodes*
25. Terminal hairs slender, less than 5μ wide; spores broadly ovoid, apiculate on one end, 6-7 × 4.5-6μ..... *C. brasiliense*
25. Terminal hairs stout, 5μ or more wide; spores lemon-shaped 8.5-10 × 7-8.5μ..... 26
26. Straight terminal hairs present..... *C. angustum*
26. Straight terminal hairs absent..... *C. cochliodes*
27. Terminal hairs tortuous, consisting of a series of reversed irregular coils.... *C. tortile*
27. Terminal hairs uniformly spirally coiled..... 28
28. Terminal hairs widespreading, coils distant below becoming closer and of decreasing diameter above..... *C. convolutum*
28. Terminal hairs with coils close and of uniform diameter..... 29
29. Terminal hairs slender, about 5μ wide; spores ovoid, 9.0-11.0 × 7.5-9.0μ... *C. spirale*
29. Terminal hairs stout, 9μ wide; spores ovoid, 7.0-8.5 × 5.0-7.0μ..... *C. aterrimum*

Terminal Hairs in Reversed Loops

30. Terminal hairs consisting of successively reversed loops with connecting arches.. 31
30. Terminal hairs consisting of successively reversed spiral coils..... *C. tortile*
31. Terminal hairs stout, about 15μ thick, arches short, loops close..... *C. contortum*
31. Terminal hairs slender, about 7μ thick, arches short, loops close..... *C. crispatum*
31. Terminal hairs slender, about 7-8μ thick, arches long, loops distant..... *C. simile*

Perithecium Elongate

32. Perithecium vase-shaped or with more or less elongated neck..... 33
32. Perithecium barrel-shaped, obclavate, or ellipsoid..... 34
33. Perithecium with greatly elongated neck; terminal hairs straight, obscurely branched above; spores lemon-shaped, 7.0-8.5 × 6-7μ..... *C. ampullare*
33. Perithecium vase-shaped with wide ostiole; terminal hairs simple, constricted at the septa, becoming irregularly branched; spores lemon-shaped, 6-7.5 × 5-6μ..... *C. torulosum*
33. Perithecium vase-shaped, with short conic ostiole; terminal hairs few, simple; spores globose-ovoid, 8-9.5 × 7-8.5μ..... *C. seminudum*
34. Perithecium barrel-shaped..... 35
34. Perithecium ellipsoid or obclavate..... 36
35. Terminal hairs slender, 4μ thick, with numerous spiral coils, lateral hairs with coiled ends; spores lemon-shaped..... *C. subspirale*
35. Terminal hairs stout, 7.5μ thick, with few coils, sometimes irregularly branched; spores angular, square..... *C. quadrangulatum*
36. Perithecium oblong-ellipsoid to cylindric, not more than 200μ wide; spore mass small, obscuring terminal hairs; terminal hairs regularly spirally coiled, with few obscure branches..... *C. microcephalum*
36. Perithecium obclavate, 150-260μ or more wide; terminal hairs coiled, frequently branched..... 37
37. Terminal hairs regularly and closely coiled, with numerous coils... *C. pachypodioides*
37. Terminal hairs becoming irregularly coiled, with irregularly coiled branches..... *C. caprinum*

CHAETOMIUM AMPULLARE Chivers, Proc. Am. Acad. Arts & Sci. 48 : 86. 1912.

(Plate II, Figs. 8-10; Plate XII, Fig. 5)

Plants black, upright, scattered, with sparse, golden-yellow hairs.

Perithecia large, (450)-525-580 × 170-190μ, flask-shaped, with elongated neck. *Terminal hairs* straight, 6-7μ wide at base, long-tapering, septate, alternate cells collapsing, usually ending in two threadlike, wavy, collapsed branches. *Lateral hairs* similar but unbranched, few. *Spores* dark-colored, lemon-shaped, strongly umbonate at both ends, 7.0-8.5 × 6.0-7.0μ, extruded in irregular clusters, often collecting at ends of terminal hairs.

The elongate, flask-shaped perithecium with straight terminal hairs, obscurely branched above, and the lemon-shaped spores easily distinguish *C. ampullare*. This species has not been isolated from seed and is known only from the type which has been examined (FH, DAOM 24950)*. A second specimen in herb. A. H. Chivers, No. 4-1, at Cornell University, (DAOM 35432), is probably part of the type collection.

CHAETOMIUM ANGUSTUM Chivers, Mem. Torrey Botan. Club, 14 : 206. 1915.

(Plate VII, Figs. 5-7; Plate XII, Fig. 2)

Plants brown, somewhat obscured at maturity by the loose mass of gray hairs.

Perithecia subglobose, 285-320 × 260-300μ. *Terminal hairs* of three types: (*a*) straight below, spirally coiled above, with four to six coils of diminishing diameter, dark-colored, coarsely roughened, 5-6μ wide at base, septa obscure, (*b*) uniformly spirally coiled with up to eight coils, finely roughened and light-colored, 1.5-2.5μ in width, (*c*) a few straight, tapering hairs, dark and roughened below, about 5μ wide at base, becoming light-colored, smooth, and evenly septate above. *Spores* dark-colored, broadly ovoid, umbonate at both ends, 8.5-9.5 × 8.0-8.5μ.

C. angustum resembles *C. cochliodes* but has coarser, more loosely coiled terminal hairs and also a few straight terminal hairs. *C. angustum* is apparently known only from the type which has been examined (FH, DAOM 24949). Specimen No. 25-1, in herb. A. H. Chivers at Cornell, (DAOM 35433), is probably from the type collection.

CHAETOMIUM ATERRIMUM Ellis & Everhart *in* Palliser H. L., N. A. Flora, 3 : 62. 1910.

(Plate VI, Figs. 7-8)

"Perithecia scattered, loosely attached, black, ovoid or subglobose, 275μ high, perforated at the apex, thin, membranaceous, densely clothed with hairs; lateral and basal hairs numerous, smooth or slightly encrusted, flexuous, light-brown, septate, in dried specimens breaking off close to the perithecium;

* *Refers to the type specimen in the Farlow Herbarium (FH) from which a slide has been taken and deposited in the Mycological Herbarium, Department of Agriculture, Ottawa (DAOM).*

apical setae dark-brown, gradually becoming almost black toward the end, thickly incrusted, 6μ thick at the base, straight for 120-180μ, then coiling 10-15 times in a close, regular spiral 400-450μ long and 50-60μ in diameter; setae at the tip 10-12μ thick; spores yellow-brown, ellipsoid, slightly apiculate at both ends, 6-7.5 × 4-5μ."

C. aterrimum is a rare species and the type, collected on damaged wheat in Kansas, which is deposited in the herbarium of the N.Y. Botanical Garden, has not been seen. The above description is taken from Palliser (8). However, slide No. 3310 in the Farlow Herbarium, received by Chivers from F. J. Seaver and presumably from the type, has been examined. The perithecia on this slide were completely crushed but the terminal hairs were found to be 8.5-9.5μ thick (somewhat narrower than in Palliser's description) and the spores oval-shaped, rounded on the ends or obscurely apiculate, 7.0-8.5 × (4.5)-5.0-7.0μ (slightly larger than in the above description).

C. aterrimum may be distinguished by the long, thick, uniformly and closely spirally coiled terminal hairs and oval spores. It most closely resembles *C. spirale* but has thicker terminal hairs and smaller spores.

CHAETOMIUM ATROBRUNNEUM Ames, Mycologia, 41 : 641. 1949.

(Plate X, Fig. 11)

Perithecia dark brown, globose to subglobose, small, 95-135 × 90-120μ, with simple, wide ostiole. *Terminal hairs* long, slender, 3.0-3.5μ wide, tapering only slightly, light-colored, smooth, septate, straight or slightly flexed, branches at wide angle and rounded at point of attachment. *Lateral hairs* similar but unbranched and with long, collapsed tips. *Spores* ellipsoid to ellipsoid-fusiform, (7.5)-8.0-10.0 × 4.0-5.0μ.

The small size of the perithecium, the long, slender, straight or flexed hairs with wide-angled branches, and the ellipsoid spores distinguish *C. atrobrunneum*.

This species has not been isolated from seed but a specimen from Ames, No. J-1041, (DAOM 24183) has been examined.

Chaetomium atrosporum sp. nov.

(Plate V, Figs. 1-4; Plate XIII, Fig. 1)

Perithecia atrobrunnea, a subglobosis ovoidea, basa obtusa, 280-300 × 225-245μ. Pili terminales longi, sinuati, 3.0-3.5μ crass., interdum ramosi, minute rugosi, haud septati. Pili laterales similes. Asci octospori, crassi, a clavatis pyriformi, 44 × 23μ. Sporae a globosis ovoideae, (13.0)-14.5-15.5-(16.5) × (12.0)-13.0-14.5μ, atrobrunneae, parietibus crassis, in latere tantum uno nonnunquam planatae, poris duobus distinctis.

Hab. in seminibus *Dauci carota* L. var. *sativae* DC.

Plants black with greenish-yellow hairs.

Perithecia dark brown, subglobose to ovoid, 280-300 × 225-245μ, somewhat pointed at the base and firmly attached to the substratum by dark-colored rhizoids. *Terminal hairs* irregularly sinuous, long, untapered, with blunt tip,

light-colored, minutely roughened, nonseptate, occasionally branched at right angles, 3-3.5μ in thickness. *Lateral hairs* similar to terminal hairs. *Asci* eight-spored, stout, clavate to pyriform, 44 × 23μ. *Spores* globose to subglobose to ovoid, often flattened on one side, dark brown, thick-walled, (13.0)-14.5-15.5-(16.5) × (12.0)-13.0-14.5μ, provided with two distinct pores.

Isolated from carrot seed from Minnesota. Type deposited in the Department of Agriculture Mycological Herbarium, Ottawa, (DAOM 19514).

C. atrosporum is easily distinguished by the large, subglobose, dark-colored spores which are not found in any other species in the genus. This species is represented by a single isolation from carrot seed (*Daucus carota* L. var. *sativa* DC.) from Minneapolis, Minn. (DAOM 19514).

CHAETOMIUM AUREUM Chivers, Proc. Am. Acad. Arts & Sci. 48 : 86-87. 1912.
Chaetomium minimum v. Beyma, Antonie van Leeuw. 10 : 42. 1944.

(Plate IV, Figs. 1-4; Plate XI, Fig. 3)

Plants black, sparsely clothed with gray hairs.

Perithecia globose to subglobose, small, 125-150 × 105-135μ, with wide, simple ostiole. *Terminal hairs* arcuate from the base and usually incurved, regularly septate, smooth to finely roughened, colored brown in the middle portion, with straight, incurved, or once-recurved blunt tips, 3.5-4.5μ wide at middle of length, narrower and lighter-colored above and below. *Lateral hairs* straight, finely roughened, septate. *Spores* unevenly ellipsoid, flattened on one side, faintly apiculate at one or both ends, dark-colored, 8.5-11.0 × 4.5-5.5μ.

C. aureum is representative of a section of the genus in which the perithecia are small and the terminal hairs are arcuate, usually incurving. The incurved tips of the terminal hairs and the ellipsoid-flattened spores distinguish *C. aureum* from *C. trilaterale* in which the hairs have coiled tips and the spores are relatively broader; from *C. fusiforme* in which the hairs have circinate tips and the spores are fusiform; and from *C. turgidopilosum* which has inflated terminal hairs and lemon-shaped spores.

C. aureum has been isolated from seeds of tomato (*Lycopersicon esculentum* Mill.) from Ontario (DAOM 15087); cucumber (*Cucumis sativa* L.) from Michigan (DAOM 15050); pepper (*Capsicum annuum* L.) from New Jersey (DAOM 14184); carrot (*Daucus carota* L. var. *sativa* DC.) from Quebec; onion (*Allium cepa* L.) from British Columbia (DAOM 24214); and oats (*Avena sativa* L.) from Quebec.

The type in the Farlow Herbarium has been examined (DAOM 24951) and of nine collections from paper, dung, butter, sphagnum, and twigs in the Chivers Herbarium, Cornell University, slides of four of them have been prepared, as follows: from guinea pig dung, Cambridge, Mass., 1904, Chivers No. 1-4, (DAOM 35434); from old paper, Hanover, N.H., 1903, Chivers No. 1-9, (DAOM 35435); from old paper, Amesbury, Mass., 1904, Chivers

No. 1-1, (DAOM 35436); and from filter paper, Cambridge, Mass., 1904, (DAOM 35437). Four cultures received from G. W. Martin, No. 6403 (DAOM 35438) and No. 6404 (DAOM 35439) of unnamed source, No. 6406 (DAOM 35440) from hemlock bark, Harbor Springs, Mich., and No. 6335 (DAOM 35441) from *Pinus virginiana*, Hamburg, Ind., are all typical of *C. aureum*.

A culture received from the Centraalbureau voor Schimmelcultures, labelled "*Chaetomium minimum* v. Beyma from podsol-böden, Netherlands", (DAOM 35442) has been found to be identical with *C. aureum*. Van Beyma (12) established *C. minimum* mainly on the basis of perithecial color differences and difference in spore size as compared with *C. aureum* but it is felt that these differences are insufficiently decisive to warrant establishment of a new species. Two cultures isolated from soil in England, IMI 22051 (DAOM 24629) and IMI 40065 (DAOM 24628), determined by S. J. Hughes as *C. trilaterale*, are also considered to be *C. aureum*.

CHAETOMIUM BOSTRYCHODES Zopf, Abh. Bot. Ver. Prov. Brandenburg, 19 : 173. 1887.

(Plate VI, Figs. 1-3; Plate XI, Fig. 7)

Plants upright, scattered, brown, with few, loosely coiled white hairs, developing a mauve-brown cast in culture.

Perithecia subglobose to ovoid 200-260 × 170-195 μ, provided with a distinct collar around the ostiole and easily visible in young perithecia. *Terminal hairs* straight below, spirally coiled above with six to eight coils of diminishing diameter, light-colored, septate, finely roughened, less than 5 μ wide at base. *Lateral hairs* simple, straight, septate, smooth, about 5 μ wide at base tapering to a long, sharp point. *Spores* broadly oval, faintly apiculate at both ends, light-colored, 7.0-8.5 × 6.0-7.0 μ, often extruded in cirrhi.

C. bostrychodes resembles *C. cochliodes* but the latter has larger perithecia, coarser hairs, and large, lemon-shaped spores. It also resembles *C. spirale* which differs, however, in having larger spores and terminal hairs with up to 14 coils.

C. bostrychodes has been isolated from seed of the following: okra (*Hibiscus esculentus* L.) (DAOM 14186); onion (*Allium cepa* L.) from Ontario (DAOM 14894 and 19503); peas (*Pisum sativum* L.) from Quebec (DAOM 15088) and Manitoba (DAOM 24188); and pepper (*Capsicum annuum* L.) from Michigan (DAOM 14185). It has also been isolated from seed of ash (*Fraxinus* sp.) from Shenyang, Manchuria (DAOM 35443). A slide of *C. bostrychodes* from oat seed from Northern Ireland (IMI 39574; DAOM 24613) was supplied by S. J. Hughes. It has also been encountered as an air contaminant at Ottawa. Specimens of *C. bostrychodes* in the Farlow Herbarium, identified by Chivers (DAOM 24952) and by Ames, 1045.1, (DAOM 35444) have been examined. Chivers' Herbarium at Cornell University, Ithaca, N.Y., contains 18 collections of this species, all from dung. Slides of three of these specimens have

been obtained as follows: Chivers No. 21-1 from goat and hog dung, Port Prince, Haiti, 1903, (DAOM 35447); Chivers No. 21-5, from rat and horse dung, Amesbury, Mass., 1912, (DAOM 35445); Chivers No. 21-12, from moose dung, Maine, 1904, (DAOM 35446).

CHAETOMIUM BRASILIENSE Batista & Pontual, Bol. Sec. Agr. Ind. e Com., Pernambuco, 15 : 70. 1948. (Orig. *C. brasiliensis*)

Chaetomium hamatum Batista & Pontual in op. cit. p. 71.
Chaetomium repandum Batista & Pontual in op. cit. p. 72.
Chaetomium velutinum Ames, Mycologia, 41 : 641. 1949.
not *C. velutinum* Ellis & Ev., J. Mycol. 1 : 90. 1885.

(Plate XI, Fig. 11)

Plants brown, clothed in gray hairs which obscure the perithecia at maturity.

Perithecia subglobose to ovoid, becoming beaked and often with pointed base, small, 90-120 × 75-90μ, dark-colored. *Terminal hairs* flexed below, becoming spirally coiled above with five to seven coils, occasionally branched, 3-4μ wide, dark-colored, septate, smooth or finely roughened, with rounded tip. *Lateral hairs* straight to flexed, septate, light-colored, finely roughened, with bulbous basal cell. *Spores* broadly ovoid, light-colored, subapiculate at one end, 6.0-7.0 × 4.5-6.0μ, monostichous in cylindric asci.

C. brasiliense may be distinguished by the small size of the perithecium, the narrow, coiled, terminal hairs, and the broadly ovoid spores, apiculate only at one end. The monostichous arrangement of the spores in the ascus is difficult to observe.

We are in agreement with S. J. Hughes, who supplied type material of the Batista and Pontual species, in his suggestion that *C. repandum*, *C. hamatum*, and *C. velutinum* are synonymous with *C. brasiliense*. Subsequently, through the courtesy of Prof. A. Chaves Batista, cultures of the Batista and Pontual species were received. The following isolations have been examined: (i) Ex type isolation of *C. brasiliense*, FIPA culture No. 78 (FIPA 1129) isolated from dung of *Cavia cobaya*, Recife, Brazil, 15.XI. 1947 (IMI 42201; DAOM 24615). (ii) Ex type isolation of *C. hamatum*, FIPA culture No. 76 (FIPA 1151) isolated from cotton lint (*Gossypium herbaceum*), Bonji Experiment Station, Recife, Brazil (IMI 42203; DAOM 24621). (iii) Ex type isolation of *C. repandum*, FIPA culture No. 79 (FIPA 1127) isolated from cotton lint (*Gossypium herbaceum*), Bonji Experiment Station, Recife, Brazil, (IMI 42202; DAOM 24626). (iv) Culture of *C. velutinum*, received from L. M. Ames, No. J-359 (probably from the type culture), isolated from a Japanese tent (DAOM 24184). (v) Culture from S. N. Basu, No. 117, isolated from rotten jute fabric, Calcutta, India, received 21. II. 1952. There can be little doubt that *C. brasiliense*, *C. hamatum*, *C. repandum*, and *C. velutinum* are identical and are referred to *C. brasiliense*, the first mentioned name.

CHAETOMIUM CANCROIDEUM Tschudy, Am. J. Botany, 24 : 478. 1937.
(For description, see Can. J. Research, C, 26 : 278. 1948.)
(Plate X, Fig. 7)

CHAETOMIUM CAPRINUM Bainier, Bull. Trimest. Soc. Myc. France, 25 : 223-224. 1909.
(Plate IX, Figs. 1-3; Plate XIII, Fig. 2)

Plants dark brown with light brown to violet hair mass.

Perithecia obclavate, narrowing above, 450-520-(630) × 225-260-(335)μ, provided with an ostiolar collar. *Terminal hairs* dark-colored, smooth to finely roughened, septate, straight below, 5-6μ thick, at first with four to five close, diminishing coils, becoming branched with numerous, loosely and irregularly coiled branches, with the basal cell of the branch inflated and rounded at point of attachment. *Lateral hairs* straight, very finely roughened, septate, dark-colored, up to 5μ thick at base, relatively short, tapering and fading to long, collapsed tip. *Spores* subglobose to ovate, apiculate at both ends, 5.0-6.0 × 3.5-5.0μ, forming a dense, irregular mass and obscuring the terminal hairs.

C. caprinum may be confused with *C. pachypodioides* from which it differs only in the character of the terminal hairs. In *C. pachypodioides* the terminal hairs are more regularly spirally coiled with longer coils which extend beyond the spore mass at maturity and have fewer branches. *C. caprinum* may resemble *C. bostrychodes* in younger stages but the much elongated perithecium of the former clearly distinguishes it.

C. caprinum has not been isolated from seed and is known only as a dung-inhabiting species. The following specimens of *C. caprinum* have been examined:

(i) In the Farlow Herbarium, on rabbit dung, Amesbury, Mass., 25. IX. 1904, A. H. Chivers (DAOM 24953).

(ii) In the Farlow Herbarium, L. M. Ames No. 1043.0 (DAOM 35449).

(iii) Ex herb. IMI 7116, on mouse dung, Cardiff, Wales, –. V. 1944, S. J. Hughes (DAOM 24616).

(iv) Ex herb. A. H. Chivers (Cornell University) No. 20-2, on muskrat dung, Amesbury, Mass., 26. X. 1912 (DAOM 35450); No. 20-11, on dog dung, New Haven, Conn., 12. –. 1888 (DAOM 35451); No. 20-12, on dung of Liberian rat, 1896 (DAOM 35452).

CHAETOMIUM CAUSIAEFORMIS Ames, Mycologia, 41 : 644. 1949.
(Plate X, Fig. 14)

Plants dark brown with light brown, widespreading terminal hairs and pale gray lateral hairs.

Perithecia globose to subglobose, small, 140 × 135μ ("80-100 × 80-90μ" (1)), translucent, provided with a distinct ostiolar collar. *Terminal hairs* of two kinds (*a*) ostiolar hairs short, irregularly and loosely looped or gnarled

and branched, smooth, obscurely septate, untapered, (*b*) long, undulating, widespreading, and branched only rarely at wide angle, smooth, septate. *Lateral hairs* straight, short, tapered to rounded tip, light-colored, septate, smooth. *Spores* subglobose to ovoid, rounded on ends, 5.0-6.5 × 4.0-5.5μ.

The small, pale, translucent perithecium with ostiolar collar, the gnarled, handlike, branched ostiolar hairs and the long, undulating, widespreading terminal hairs distinguish *C. causiaeformis* from all other species.

A specimen of *C. causiaeformis*, received from Ames, No. J-1334, (DAOM 24186), presumably from the type culture, has been examined.

CHAETOMIUM CIRCINATUM Chivers, Mem. Torrey Botan. Club, 14 : 168. 1915.
(Plate III, Figs. 5-7)

Plants black with loose, widespreading, gray hairs.

Perithecia globose to subglobose, large, "270-340 × 258-335μ" (4), dark brown, with simple, small ostiole. *Terminal hairs* dark brown, smooth, thick-walled, septate, up to 7μ wide, long, undulate, with circinate tip, two to three times recurved. *Lateral hairs* light brown, smooth, septate, straight to flexed, with rounded or collapsed straight tip. *Spores* ellipsoid, slightly umbonate at both ends, brown, 12-16 × 7.5-9.5μ.

C. circinatum is distinguished by the thick, long, undulate terminal hairs with circinate tips, and by the large, ellipsoid spores. *C. murorum*, which resembles this species, has narrower hairs with incurved tips and smaller spores.

C. circinatum is a rare species, known only from the type in the Farlow Herbarium from old burlap, Worcester, Mass., (DAOM 35453). A specimen in the Chivers Herbarium, No. 12-1, from burlap, Worcester, Mass., 1903, (DAOM 35454), is probably from the type collection.

CHAETOMIUM COCHLIODES Palliser, N.A. Flora, 3 : 61. 1910.
(Plate VII, Figs. 1-4; Plate XII, Fig. 6)

Plants yellowish-green, olive-green, or chocolate-brown, with perithecia and spore mass obscured at maturity by compact mass of hairs.

Perithecia subglobose, 335-375 × 300-350μ. *Terminal hairs* (*a*) straight below, spirally coiled above with three to five coils, dark-colored, covered with coarse projections, 5-7μ thick below, projecting beyond spore mass, and (*b*) more slender, lighter-colored hairs, about 3.5μ thick, slightly roughened with up to seven loose coils. *Lateral hairs* numerous, straight or slightly flexed, finely roughened, septate, up to 5μ wide at base. *Spores* dark-colored, broadly ovoid, umbonate at both ends, 9.0-10.5 × 8.0-8.5μ.

C. cochliodes is very similar to *C. angustum* but lacks the straight terminal hairs of the latter and forms a more compact mass of hairs. *C. cochliodes* has, in addition to the fine, loosely coiled or sinuous terminal hairs similar to those of *C. globosum*, coarse terminal hairs, straight below and coiled above, frequently extending beyond the interwoven mass of terminal hairs. In young perithecia of *C. cochliodes* the lower part of the terminal hairs is straight, whereas in *C. globosum* the terminal hairs are sinuous from the base.

C. cochliodes is a very common species and has been isolated from seed of the following: leek (*Allium porrum* Linn.) from British Columbia (DAOM 14187); oats (*Avena sativa* L.) from Quebec and Ontario; swedes (*Brassica napobrassica* Mill.) from New Brunswick (DAOM 7394 and 7397) and Prince Edward Island (DAOM 20074); cabbage (*Brassica oleracea* L. var. *capitata* L.) from Quebec (DAOM 14895); turnip (*Brassica rapa* L.) from Minnesota (DAOM 14188); pepper (*Capsicum annuum* L.) from Ohio (DAOM 14189); muskmelon (*Cucumis melo* L.) from New Jersey (DAOM 14190); vegetable marrow (*Cucurbita pepo* L.) source unknown (DAOM 7401); flax (*Linum usitatissimum* Linn.) from Quebec (DAOM 15198) and Saskatchewan (DAOM 20073); soybeans (*Glycine max* Merr.) from Quebec (DAOM 13387); alfalfa (*Medicago sativa* L.) from Alberta (DAOM 7400); parsnip (*Pastinaca sativa* L.) from California (DAOM 7398); parsley (*Petroselinum hortense* Hoffm.) from Michigan (DAOM 19517); peas (*Pisum sativum* L.) from Ontario (DAOM 13389 and 18073), Saskatchewan, and British Columbia (DAOM 20070, 20071, 20072); beans (*Phaseolus vulgaris* L.) from Ontario (DAOM 35455); New Zealand spinach (*Tetragonia expansa* Murr.) from California (DAOM 15759); red clover (*Trifolium pratense* L.) from Quebec (DAOM 7399); broad beans (*Vicia faba* L.) from British Columbia (DAOM 13390); and from corn (*Zea mays* L.) from Ontario (DAOM 13392). Specimens of *C. cochliodes* have also been obtained from oat stems in Ontario (DAOM 24191), from leaves of *Catalpa* sp. from Quebec (DAOM 19675) and from stems of *Eriophorum* sp. (G. W. Martin No. 6401).

The following specimens of *C. cochliodes* have been examined: (i) *C. cochliodes*, ex Farlow Herbarium, from caterpillars, Reading, Mass., 20.I. 1906, identified by A. H. Chivers (DAOM 35456). (ii) Sub *C. globosum*, ex Farlow Herbarium, from refuse, Waverley, Mass., 28.X. 1903, (DAOM 35457). (iii) *C. cochliodes*, ex herb. IMI 31195, contaminant of Petri dish culture, Kew, Eng., –. VI. 1948, identified by S. J. Hughes (DAOM 24614). (iv) Sub *C. setosum* Bainier, from Centraalbureau voor Schimmelcultures, received 18.XI. 1946, (DAOM 19451). (v) Sub *C. convolutum* Chivers, from Centraalbureau voor Schimmelcultures, received 18.XI. 1946 (DAOM 19446). (vi) *C. cochliodes*, ex herb. A. H. Chivers (Cornell) No. 24-3, culture on rabbit dung from collection on barrel hoops, Amesbury, Mass., 11. III. 1904 (DAOM 35458). (vii) Sub *C. olivaceum* C. & E. var. *chartarum*, ex herb. Cornell 1910, identified by Jackson, (DAOM 35459). In his herbarium at Cornell, Chivers has deposited collections of *C. cochliodes* from such varied substrata as wood, paper, dung, leather, dead plant parts from both temperate and tropical regions.

CHAETOMIUM CONTORTUM Peck. Rep. N.Y. State Mus. Nat. Hist. 49 : 24. 1896.

(Plate VIII, Figs. 1-2; Plate XIII, Fig. 9)

Perithecia globose or subglobose, dark brown, large, "875 × 1050μ" (4). *Terminal hairs* dark brown, obscurely septate, coarsely roughened, contorted

into reversed loops with short arches, up to 15μ wide in thickest part of loop, ending in an incurved blunt tip. *Lateral* hairs light brown, septate, straight or slightly contorted, finely roughened, about 5μ thick at base. *Spores* "when mature dark rich olive-brown, irregularly lemon-shaped, not always symmetrical, sometimes apiculate at ends, sometimes barely angular, 11.6 × 9.4μ (10.5-12.5 × 7.5-10.5)" (4).

C. contortum resembles *C. crispatum* and *C. simile* in having the terminal hairs contorted in reversed loops. It differs, however, in the large size of the perithecium and in the stout hairs with short arches. It is known only from the type.

A type slide of *C. contortum* in the Farlow Herbarium, No. 3324, has been examined but the absence of spores in this slide makes it necessary to quote the spore description from Chivers. A second specimen in the Farlow Herbarium, identified by Ames No. 1044.9 as *C. contortum*, has been found to be identical with *C. crispatum* (DAOM 35461).

CHAETOMIUM CONVOLUTUM Chivers, Proc. Am. Acad. Arts & Sci. 48 : 85. 1912.
(Plate XII, Fig. 4)

Plants light brown with few, loose, widespreading hairs.

Perithecia light brown, subglobose, sometimes narrowed below, 275-300 × 250-275μ. *Terminal hairs* straight below, becoming undulate to loosely coiled to tightly coiled with about six close coils of decreasing diameter toward the end of the hair, dark brown, conspicuously roughened, obscurely septate, about 8-8.5μ wide at base. *Lateral hairs* light brown, straight, septate, finely roughened, tapering to long, collapsed tip, about 5μ wide at base. *Spores* ovoid to ovoid-ellipsoid, lightly colored, faintly apiculate at one or both ends, 7.0-8.5-(9.0) × 5.5-7.0μ.

The widespreading, coiled terminal hairs with the coils distant and of wide diameter below, constantly becoming closer and of smaller diameter, distinguish *C. convolutum* from other species.

C. convolutum is known only from the type, from mouse dung, Germany, 20. II. 1906, which has been examined in the Farlow Herbarium (DAOM 24955). Several collections from the type isolation, ex herb. A. H. Chivers, No. 18, (DAOM 35460) have also been examined. A culture received from the Centraalbureau voor Schimmelcultures, 18. XI. 1946, identified as *C. convolutum* by Wilkins, has been found to be *C. cochliodes* (DAOM 19446).

CHAETOMIUM CRISPATUM Fuckel, Symb. Myc. 90. 1869.
(Plate VIII, Figs. 6-8; Plate XIII, Fig. 11)

Plants obscured by loose mass of light to dark brown hairs.

Perithecia subglobose, opaque, with simple ostiole, 300-310 × 310-335μ. *Terminal hairs* dark brown, with few, obscure septations, coarsely roughened, consisting of a series of successively reversed loops with connecting, short

arches, about 7μ wide at broadest point, ending in a stout, circinate, blunt tip. *Lateral hairs* light brown, finely roughened regularly septate, 4.5-5.0μ wide at base, straight, with long, collapsed tip. *Spores* dark-colored, broadly ovoid, umbonate at both ends, 9.0-11.0 × 7.5-9.5μ.

C. crispatum could be confused only with *C. contortum* which has larger perithecia and wider, more coarsely roughened terminal hairs, or with *C. simile* which has smaller perithecia and smoother, longer arches in the terminal hairs.

C. crispatum has not been isolated from seed but the following specimens have been examined: (i) Ex herb. Farlow, from dung, Cambridge, Mass., A. H. Chivers (DAOM 24956). (ii) Sub *C. contortum*, ex herb. Farlow, –. VI. 1944, L. M. Ames, No. 1044.9, (DAOM 35461). (iii) Ex. herb. A. H. Chivers (Cornell), No. 9-1, cow dung, Amesbury, Mass., 1906, (DAOM 35462). (iv) Ex herb. A. H. Chivers (Cornell), No. 9-5, opossum dung, Sandy Run, S. Carolina, 1905, (DAOM 35463).

CHAETOMIUM CRISTATUM Ames, Mycologia, 41 : 639. 1949.
(Plate II, Figs. 5-7; Plate X, Fig. 10)

Plants brown, obscured by the mass of gray hairs.

Perithecia yellow to light brown, globose to subglobose, "250-300 × 175-225μ" (1), with wide, simple ostiole. *Terminal hairs* of two kinds (*a*) essentially straight or slightly flexed, erect, broad, 5-6μ wide, dark-colored, untapered, nonseptate, finely roughened, unbranched except at the tip where a few short irregular branches or short irregular coils may be present, and (*b*) shorter, very fine, 1.5-2μ wide, light-colored, irregularly branched. *Spores* ellipsoid, "umbonate to subapiculate, olive-brown, 8-12 × 4.5-6μ" (1).

The wide ostiole, broad, untapered, erect terminal hairs with irregularly branched or short coiled tips, and the ellipsoid spores distinguish *C. cristatum* from all other species.

C. cristatum has not been isolated from seed. A young collection ex herb. L. M. Ames, 1.V. 1945, (DAOM 24581) has been examined but, because of the immaturity of the perithecia, it has been necessary to quote perithecial and spore size from Ames' original description.

CHAETOMIUM CUNICULORUM Fuckel, Symb. Myc. 89. 1870.
(For description, see Can. J. Research, C, 26 : 274. 1948.)

CHAETOMIUM DOLICHOTRICHUM Ames, Mycologia, 37 : 145. 1945.
(For description, see Can. J. Research, C, 26 : 274-275. 1948.)
(Plate X, Fig. 2)

CHAETOMIUM ELATUM Kze. ex Fries, Deutsch. Schw. 8 : 3. 1818.
(For description, see Can. J. Research, C, 26 : 272-273. 1948.)
(Plate X, Fig. 1)

CHAETOMIUM ERECTUM Skolko & Groves, Can. J. Research, C, 26 : 277-278. 1948.
(Plate X, Fig. 6)

CHAETOMIUM FUNICOLA Cooke, Grev. 1 : 176. 1873.
(For description, see Can. J. Research, C, 26 : 275. 1948.)
(Plate X, Fig. 3)

CHAETOMIUM FUSIFORME Chivers, Proc. Am. Acad. Arts & Sci. 48 : 87. 1912.
(Plate IV, Figs. 9-11; Plate XI, Fig. 5)

Plants dark brown, very small, with light brown hairs.

Perithecia subglobose to ovoid, opaque, small, 135-165 × 120-150μ, with wide simple ostiole. *Terminal hairs* dark brown, smooth, septate, arcuate with once- to twice-recurved tips, 2.5-3.5μ wide. *Lateral hairs* light brown, smooth, septate, straight or curved at top, short, 1.5-2.5μ wide. *Spores* dark brown, fusiform and flattened on one side, 12-16-(17) × 5-6μ.

C. fusiforme may be distinguished by its fusiform spores and arcuate hairs with circinate tips.

The type of *C. fusiforme*, deposited in the Farlow Herbarium, could not be found. However, a specimen in the Chivers Herbarium (Cornell), No. 3, on paper with sparrow dung, Alabama, 1904, (DAOM 35496), is probably from the type isolation. Through the courtesy of Dr. R. Heim, a culture of *C. fusiforme* from the Muséum d'Histoire Naturelle, Paris, No. 516, isolated from soil, French Congo, was received 21. IV. 1950, (DAOM 24218) and found to be identical with Chivers' specimen.

CHAETOMIUM GANGLIGERUM Ames, Mycologia, 41 : 640. 1949.
(Plate XI, Fig. 8)

Plants dark brown to black with gray hairs.

Perithecia subglobose to ovoid (cylindric when young) "230-260 × 190-210μ" (1), opaque, with simple ostiole. *Terminal hairs* light yellow, finely roughened, septate, 3-4μ wide, straight below, spirally coiled above with three to seven coils, occasionally up to 11 coils of uniform diameter, tip blunt. *Lateral hairs* light yellow, smooth, septate, straight or irregularly flexed. *Spores* dark-colored, ovoid-ellipsoid, rounded on ends or faintly umbonate, 10-13 × 7-8.5μ.

C. gangligerum most closely resembles *C. bostrychodes* but differs from the latter in having larger, darker spores, "dark-celled bulbils it produces in the agar" (1), and the uniform diameter of the coils of the terminal hairs.

This species has not been found on seeds but a young specimen has been received from Ames, (DAOM 24185).

CHAETOMIUM GLOBOSUM Kunze, Myc. Hefte, 1 : 15-16. 1817.

Chaetomium deustum Batista & Pontual, Bol. Sec. Agr. Ind. e Com., Pernambuco, 15 : 72. 1948.

Chaetomium subterraneum Swift and Povah, Mycologia, 21 : 210. 1929.

(Plate V, Figs. 9-13; Plate XII, Fig. 8)

Plants variable in color, gray, green to brown.

Perithecia opaque, subglobose 250-300 × 245-275μ.

Terminal hairs light-colored, finely roughened, obscurely septate, slender, about 3μ wide, undulate below, becoming sinuous or very loosely coiled above, or long undulate throughout, forming a dense, interwoven mass. *Lateral hairs* light-colored, finely roughened, septate, 3.5μ wide at base, long, slender, irregularly flexed. *Spores* dark-colored, broadly ovoid, faintly apiculate at both ends, 8.0-9.5 × 6.0-8.0μ.

C. globosum is a variable species, sometimes confused with *C. cochliodes* which has coarser terminal hairs with straight base and definitely coiled upper part and somewhat larger spores; with *C. ochraceum* which has finer, more sinuous hairs; and with *C. sphaerale* which has branched hairs and perithecium narrowed at the ostiole. Certain isolates of *C. globosum*, in which the terminal hairs are long undulate and not sinuous or coiled, closely resemble *C. olivaceum* but differ from the latter in the narrower hairs and smaller spores.

C. globosum is the commonest species isolated from seed. It has been found on seed of red top (*Agrostis alba* L.) from Ontario (DAOM 18349); onion (*Allium cepa* L.) from Japan (DAOM 7419), and from British Columbia; oats (*Avena sativa* L.) from Ontario (DAOM 35530) and Quebec; mangel (*Beta vulgaris* L.) from New Brunswick (DAOM 7930); swiss chard (*Beta vulgaris* L. var. *cicla* L.) from California (DAOM 7395); swedes (*Brassica napobrassica* Mill.) from British Columbia; cauliflower (*Brassica oleracea* L. var. *botrytis* DC.) from Denmark (DAOM 7416); cabbage (*Brassica oleracea* L. var. *capitata* L.) from Quebec (DAOM 35527); safflower (*Carthamus tinctorius* L.) from Ontario; muskmelon (*Cucumis melo* L.) from Michigan (DAOM 14199); cucumber (*Cucumis sativa* L.) from Quebec (DAOM 35528); squash (*Cucurbita maxima* Duch.) from Connecticut (DAOM 7417); vegetable marrow (*Cucurbita pepo* L.) from Quebec (DAOM 24195); carrot (*Daucus carota* L. var. *sativa* DC.) from Quebec (DAOM 20014); meadow fescue (*Festuca elatior* L.) from Ontario (DAOM 15034); red fescue (*Festuca rubra* L.) from Alberta; soybeans (*Glycine max* Merr.) from Ontario; okra (*Hibiscus esculentus* L.) source unknown (DAOM 14191); flax (*Linum usitatissium* Linn.) from Quebec (DAOM 14899); rye grass (*Lolium perenne* L.) from Ontario (DAOM 18350); tomato (*Lycopersicon esculentum* Mill.) from Michigan (DAOM 7418), from Ontario (DAOM 13388, 14896, 19510), from Quebec (DAOM 20015); parsnip (*Pastinaca sativa* L.) from British Columbia; beans (*Phaseolus vulgaris* L.) from British Columbia, from Ontario (DAOM 24194), and from California; timothy (*Phleum pratense* L.) from Ontario; peas (*Pisum sativum* L.) from Ontario (DAOM 7389, 7502, 14200, 20077), from

Michigan, and from British Columbia (DAOM 20078); Canada blue grass (*Poa compressa* L.) from Ontario (DAOM 15762); Kentucky blue grass (*Poa pratensis* L.) from Ontario (DAOM 19449); radish (*Raphanus sativus* L.) from England (DAOM 7484); millet (*Setaria italica* (L.) Beauv.) from unknown source (DAOM 35525); spinach (*Spinacia oleracea* L.) from Ontario (DAOM 7504); Russian dandelion (*Taraxacum kok-saghyz* Rod.) from Russia (DAOM 7928), and from Nova Scotia (DAOM 14898); alsike (*Trifolium hybridum* L.) from Ontario; wheat (*Triticum aestivum* L.) from Ontario (DAOM 35529); hairy vetch (*Vicia villosa* Roth.) from Ontario (DAOM 15763); and corn (*Zea mays* L.) from Ontario (DAOM 7413, 7414, 13391, 13394, 13395, 15089, 15092).

C. globosum has also been isolated from seed of several forest tree species, as follows: balsam fir (*Abies balsamea* (L) Mill.) from Ontario (DAOM 24215); ash (*Fraxinus* sp.) from Shenyang, Manchuria (DAOM 24180); pine (*Pinus* sp.) from Shenyang, Manchuria (DAOM 24199); and from elm (*Ulmus* sp.) from Ontario (DAOM 35526).

Specimens of *C. globosum* from various other substrata have also been received, as follows: paper from Calcutta, India (IMI 16203; DAOM 24620), from Lahore, Pakistan (S. Ahmad, No. 3000) and from Salinas, Ecuador (G. W. Martin, No. 6336; DAOM 24176); *Saccharum munja* Roxb. (S. Ahmad, No. 4200) from Ladhar, Sheikhupura; *Crotalaria juncea* L. (S. Ahmad, No. 4201) from Ladhar, Sheikhupura; dead wood (S. Ahmad, No. 2211; DAOM 24193) from Ladhar, Sheikhupura; grass (G. W. Martin, No. 6391) from Talara, Peru (DAOM 35524); *Eragrostis* sp. (Allyre, No. 1746; DAOM 19676) from La Trappe, Quebec; leaves (G. W. Martin, No. 6378; DAOM 24179 and No. 6379; DAOM 24175) from Fort Sherman, Canal Zone; strawberry (*Fragaria virginiana* Mill.) from Ste. Anne de la Pocatière, Quebec, (Payette, No. 41 and No. 55); goat dung from South Seymour Is., Galapagos (G. W. Martin, No. 6287; DAOM 35499); rubber from Goodrich (G. W. Martin, No. 6405; DAOM 35523); contaminant from Iowa City, Iowa (G. W. Martin, No. 6400; DAOM 24196); and from unknown substrate from Michigan (G. W. Martin, No. 6402; DAOM 24197).

Two specimens of *C. globosum* in the Farlow Herbarium, Ames No. 1042.4 "from American type collection" (DAOM 35498) and Ames No. 1043.5 (DAOM 35497) have been examined. It has also been possible to examine the following specimens of *C. globosum* in Chivers Herbarium (Cornell): No. 26-1, on old paper, Amesbury, Mass., 23. XII. 1894; No. 26-3, on rabbit dung, Amesbury, Mass., 3. –. 1904; No. 26-4, on barrel hoops, Amesbury, Mass., 15. XII. 1904; No. 26-5, on opossum dung, Sandy Run, S. Carolina, 1905; No. 26-6, on dung, Raleigh, N. Carolina, 10. I. 1905; No. 26-7, on mouse dung, Cambridge, Mass., 24. II. 1904; No. 26-8, on dog food, Cambridge, Mass., 16. XII. 1904; No. 26-9, on dog dung, Cambridge, Mass., 1904; No. 26-12, on squash, Hanover, N. H., 28. XII. 1904; No. 26-13, old wood, Worcester, Mass., 1904; No. 26-14, on corn husks, Worcester, Mass., 1. XII. 1904; No. 26-16, on straw, New York, 12. I. 1905; No. 26-18, on

corn husks, Amboy, Ill., 1904; No. 26-19, on paper, Waverley, Mass., 28. X. 1905; No. 26-10, on grass, Hanover, N. H., 24. XI. 1904; No. 26-20, on banana leaves, South, 20. I. 1904; No. 26-21, on leaves, –. X. 1903; No. 26-22, on bread, Cambridge, Mass., 24. II. 1904; No. 26-24, on paper, Cambridge, Mass., 1904; No. 26-38, on deer dung, Norumbega Park, Mass., 1904; and No. 26-44, on straw, Nairobi, Congo, 1904.

Sub *C. kunzeanum* Zopf (= *C. globosum* Kze.) in Roum, Fung. Sel. Gall. 4436, only *C. murorum* Cda. could be found. *C. olivaceum* Cke. & Ellis in E. & E. Fung. Columb. 512, was found to consist only of *C. funicola* Cke. *C. olivaceum* Cke. & Ellis *f. chartarum* Roum. (= *C. globosum* Kze.) in Roum. Fung. Sel. Gall. 4930, consists of *C. elatum* Kze. ex Fr. and what appear to be young perithecia of *C. cochliodes* Palliser.

A culture from the type isolation of *C. deustum* Batista & Pontual F. I. P. A. culture No. 77, (FIPA 1152; IMI 42200; DAOM 24617), from leaves of *Manihot utilissima*, Recife, Brazil, agrees in every respect with *C. globosum* and is considered to be synonymous.

Tschudy (11) proposed that a variant of *C. globosum* be separated as *C. globosum* var. *affine* because the terminal hairs were definitely coiled on certain media and the perithecia were relatively longer. The wide variability of *C. globosum* warrants an extensive and critical review before any attempt to subdivide the species is made. Tschudy also examined a culture of the type isolation of *C. subterraneum* and found it identical with *C. globosum*.

CHAETOMIUM INDICUM Corda, Icon. 4 : 38. 1840.
(For description, see Can. J. Research, C, 26 : 276. 1948.)
(Plate X, Fig. 5)

CHAETOMIUM MICROCEPHALUM Ames, Mycologia, 37 : 145. 1945.
(Plate IX, Figs. 7-9; Plate XIII, Fig. 3)

Perithecia ellipsoid when young, becoming oblong-cylindrical, translucent, 500-575-(670) × 150-200μ. *Terminal hairs* light-colored, septate, very finely roughened, short, stout, about 5μ wide at base, straight below, spirally coiled above with about seven to eight close coils, occasionally with coiled branches and basal cell rounded at point of attachment, terminal hairs obscured at maturity by small compact mass of spores. *Lateral hairs* light-colored, septate, roughened, straight with long tapering point, about 4.5-5.0μ wide at base. *Spores* light-colored, broadly ovoid, apiculate at both ends, 6.0-7.0 × 5.0-5.5μ.

The cylindric perithecium with the short, coiled terminal hairs, obscured by the small mass of spores, distinguish *C. microcephalum*.

The species has not been isolated from seed and is probably known only from the type, Ames No. 1045.0, in the Farlow Herbarium (DAOM 24959). One of Ames' original cultures was received from J. A. Stevenson (DAOM 35533).

CHAETOMIUM MURORUM Corda, Icon. 1 : 24. 1837.
(Plate III, Figs. 1-4; Plate X, Fig. 13)

Plants dark brown, with a loose mass of gray-brown hairs.

Perithecia globose to subglobose, opaque, 240-300 × 240-300μ, with small, simple ostiole. *Terminal hairs* dark-colored, smooth, obscurely septate, about 6μ wide, long undulate with graceful arches, widespreading, ending in an open, circinate, blunt tip. *Lateral hairs* similar to terminal hairs but straight to slightly flexed and tapering to straight, long, pointed tip. *Spores* dark-colored, ellipsoid, slightly umbonate at one end, 11.0-14.0 × 7.0-8.0μ.

The long, undulate hairs with incurved tips and the ellipsoid spores distinguish *C. murorum* from all species except *C. circinatum* which has however, stouter hairs with recurved circinate tips and larger spores.

C. murorum has been isolated from seed of beet (*Beta vulgaris* L.) from Ohio (DAOM 14902) and Quebec (DAOM 35534); swiss chard (*Beta vulgaris* L. var. *cicla* L.) from California (DAOM 15094); cucumber (*Cucumis sativa* L.) from British Columbia; squash (*Cucurbita maxima* Duch.) from British Columbia (DAOM 7906) and from Michigan (DAOM 7907); lettuce (*Lactuca sativa* L.) from Connecticut (DAOM 7904); flax (*Linum usitatissimum* L.) from Manitoba; tomato (*Lycopersicon esculentum* Mill.) from Manitoba; parsnip (*Pastinaca sativa* L.) from Michigan; parsley (*Petroselinum hortense* Hoffm.) from Ohio (DAOM 19515); and peas (*Pisum sativum* L.) from Ontario (DAOM 7905) and from Alberta (DAOM 35536).

Two collections of *C. murorum* in the Farlow Herbarium have been examined, one from cow dung, identified by Chivers (DAOM 35537) and the other identified by Ames, No. 1044.8 (DAOM 35538). In the Chivers Herbarium, Cornell, the following collections of *C. murorum* have been seen: No. 13-1, on old strawberry box, Amesbury, Mass., 27. X. 1904; No. 13-2, on old barrel hoop, Amesbury, Mass., 27. X. 1904 (DAOM 35539); No. 13-3, on paper, New Haven, Conn.; No. 13-4, on guinea pig dung, Hanover, N. H., 1905; No. 13-5, on rat dung, Hanover, N. H., 1906; No. 13-7, culture of chips, Amboy, Ill., 1902; No. 13-6, on hog dung, Lowell, Mass., 25. II. 1910; No. 13-8, on dog dung, Cambridge, Mass., 1904 (DAOM 35540); No. 13-9, on sheep dung, Cambridge, Mass., 1904 (DAOM 35541); No. 13-10, on old grass, Cambridge, Mass., 1906; No. 13-11, on rabbit dung, Cambridge, Mass., 1904; No. 13-12, on horse dung, Cambridge, Mass., 26. X. 1912 (DAOM 35542); and No. 13-13, on muskrat dung, Cambridge, Mass., 26. X. 1912. A collection, isolated from soil in England (IMI 36633), identified by S. J. Hughes, has been examined (DAOM 24623). The specimens in Roum. Fung. Sel. Gall. 4436, sub *C. kunzeanum* Zopf and in D. Sacc. Myc. Ital. 1475, sub *C. pannosum* Wallr. are both *C. murorum*.

CHAETOMIUM OCHRACEUM Tschudy, Am. J. Botany, 24 : 475. 1937.
(Plate V, Figs. 5-8; Plate XII, Fig. 1)

Plants green with rusty-orange mycelium.

Perithecia globose, about 375μ in diameter, opaque. *Terminal hairs* light-colored, smooth, nonseptate, very narrow, 1.5-2.0μ, irregularly sinuous or loosely coiled, interwoven into a large, dense, compact head. *Lateral hairs* similar but short, less sinuous, irregular, and appressed. Spores dark-colored, ovoid, faintly apiculate or umbonate at both ends, 7.0-8.5 $\times$ 5.5-6.5μ.

The extremely fine, sinuous terminal hairs, interwoven into a dense mass, smaller spores, and the ochraceous mycelium separate *C. ochraceum* from *C. globosum* which it most closely resembles.

C. ochraceum has been isolated only once from seed. It was found on oats (*Avena sativa* L.) from Quebec (DAOM 35543).

A specimen of *C. ochraceum* in the Farlow Herbarium, identified by Ames, No. 1044.5, has been examined (DAOM 35544). A culture of *C. ochraceum*, identified by Tschudy, was also received from the Centraalbureau voor Schimmelcultures (DAOM 19448).

CHAETOMIUM OLIVACEUM Cooke & Ellis, Grevillea, 6 : 96. 1878.
(Plate XI, Fig. 2)

Plants gray-green with loose mass of gray hairs.

Perithecia opaque, globose, about 395μ in diameter. *Terminal hairs* dark-colored, distinctly roughened, septate, 3-5μ wide, long, undulate, loosely interwoven. *Lateral hairs* similar but only slightly flexed, ending in a hyaline, blunt tip. *Spores* dark brown, broadly ovoid, umbonate at both ends, 9.0-12.5 $\times$ 7.5-9.0μ.

C. olivaceum closely resembles certain isolates of *C. globosum* but differs from the latter in having larger perithecia, wider terminal hairs, and larger spores.

A collection of *C. olivaceum* from oat seed, Northern Ireland, (IMI 24325), identified by S. J. Hughes, has been examined (DAOM 24505). After examining the type material of *C. olivaceum* Cke. & Ellis, which was admittedly in poor condition, Chivers (4) concluded that this species was identical with *C. globosum* and relegated it to synonymy. Hughes has recently re-examined the type of *C. olivaceum* and is convinced that it is distinct from *C. globosum* and that *C. olivaceum* is a fairly common species in England at least. Hughes is of the opinion that the more robust character of *C. olivaceum*, especially the larger spores, a fundamental character in species separation, is sufficient to warrant retention of this species.

CHAETOMIUM PACHYPODIOIDES Ames, Mycologia, 37 : 145-146. 1945.
(Plate IX, Figs. 4-6; Plate XIII, Fig. 6)

Plant black covered with gray hairs.

Perithecia ovoid-elongate, narrowing above, 350-460 $\times$ 150-260μ. *Terminal hairs* dark-colored, smooth to finely roughened, septate, straight below, 5μ

thick, evenly spirally coiled above, with up to 14 coils, gradually diminishing in diameter and extending beyond the mass of spores at maturity, with few coiled branches, rounded at point of attachment. *Lateral hairs* straight, dark-colored below, fading above, tapering gradually to pale, sharp tip, septate, finely roughened, 3.5μ thick at base. *Spores* globose or subglobose, faintly apiculate at both ends, 5.5-7.0 $\times$ 4.0-5.5μ, extruded as an irregular mass.

C. pachypodioides resembles *C. caprinum* but differs in having long, regularly coiled terminal hairs with few branches. *C. caprinum* has irregularly coiled hairs with fewer coils and many irregularly coiled branches, obscured by the spore mass. *C. pachypodioides* has a much elongated perithecium not found in *C. bostrychodes* with which it might be confused.

C. pachypodioides has not been isolated from seed and is known only from the type. Ames' collection 1044.3 (DAOM 24961) in the Farlow Herbarium has been seen, as well as a culture received from J. A. Stevenson from an original culture from Ames (DAOM 20676).

CHAETOMIUM QUADRANGULATUM Chivers, Proc. Am. Acad. Arts & Sci. 48 : 85. 1912.

(Plate XII, Fig. 3)

Plants brown, upright, distinct, with sparse, brown, white-tipped hairs and spores in cirrhi.

Perithecia opaque, barrel-shaped, 485-530 $\times$ 385-400μ. *Terminal hairs* dark brown, coarsely roughened, distinctly and closely septate, up to 7.5μ wide at base, either straight throughout or straight below and sinuous or spirally coiled above with few coils and ending in a straight to irregularly flexed, long, pointed tip, sometimes branched, with branches flexed, sinuous, or coiled, and cell at point of attachment rounded. *Lateral hairs* dark brown below, fading above, coarsely roughened, septate, about 7.0μ wide at base, straight, tapering to long, collapsed, hyaline tip. *Spores* light-colored, quadrangular, square to slightly elongate, angles rounded, 5.5-6.5 $\times$ 5.0-6.0μ when measured on the diagonals, ovate in side view.

C. quadrangulatum resembles *C. tetrasporum* and *C. trigonosporum* in having angular spores but the spores of *C. quandrangulatum* normally are regularly square, whereas those of *C. tetrasporum* are irregularly rectangular to lemon-shaped and much larger, and those of *C. trigonosporum* are triangular.

The type of *C. quadrangulatum* in the Farlow Herbarium has been examined (DAOM 24962) as well as two collections in Chivers Herbarium, Cornell, as follows: No. 29-2, from dog dung, Cambridge, Mass., 10. I. 1905 (DAOM 35545); No. 29-7, from dung, Little Swan Is., West Indies, 1. III. 1906 (DAOM 35546). It has not been found on seeds.

CHAETOMIUM REFLEXUM Skolko & Groves, Can. J. Research, C, 26 : 279. 1948.

(For description, see loc. cit.)

(Plate X, Fig. 8)

CHAETOMIUM SEMINUDUM Ames, Mycologia, 41 : 642. 1949.
(Plate II, Figs. 1-4; Plate XIII, Fig. 10)

Plants extremely small, dark brown, with few hairs, spores extruded in cirrhi.

Perithecia translucent, becoming dark brown, vase-shaped with conic ostiole, small, 165-195-(200) × 80-100-(110)μ. *Terminal hairs* sparse, short, straight, erect, unbranched, septate below, smooth, light-colored 3.5μ wide, with basal cell inflated, tapering to narrow, rounded tip, ostiolar hairs slender, short, erect. *Lateral hairs* sparse, short, light-colored, smooth, septate, ascending, about 3μ wide, basal cell inflated, tapering to rounded tip. *Spores* subglobose, to broadly ovoid, dark-colored, subapiculate at one or both ends, 8.0-9.5 × 7.0-8.5μ.

The small, thin-walled, vase-shaped perithecium with short, conic ostiole, the sparse, erect, unbranched terminal hairs, and the larger, subapiculate spores of *C. seminudum* distinguish it from *C. torulosum* which it most closely resembles.

C. seminudum has been isolated from seed of tomato (*Lycopersicon esculentum* Mill.) from Pennsylvania (DAOM 15042). A collection of this species has also been received from Ames (DAOM 24579). In his description of *C. seminudum*, Ames (1) gives the range of spore size as 9-14 × 7-8μ and an average size of 13.5 × 11μ. The average dimensions given must be a typographical error since the width is beyond the range.

CHAETOMIUM SIMILE Massee & Salmon, Ann. Botany, 16 : 71. 1902.
(Plate VIII, Figs. 3-5; Plate XIII, Fig. 7)

Plants steel-gray with loose, widespreading hairs.

Perithecia subglobose to ovoid but broader than long, 185-260 × 200-340μ. *Terminal hairs* dark brown, smooth to minutely roughened, obscurely septate, 7-8μ wide, consisting of successively reversed loops with long arches, ending in a circinate, rounded tip. *Lateral hairs* extremely fine, light-colored, interwoven threads, appearing as a narrow, matlike zone around the perithecium. *Spores* dark-colored, ovoid, faintly apiculate at one end and rounded at the other, sometimes subapiculate at both ends, 8.5-10.0 × 6.5-8μ.

C. simile resembles *C. contortum* and *C. crispatum*. It differs from *C. contortum* in having smaller perithecia, narrower, smooth terminal hairs with long arches, and lacks differentiated lateral hairs. It differs from *C. crispatum* in which the terminal hairs are coarsely roughened and the connecting arches are short.

Slide No. 3381, in the Farlow Herbarium, of *C. simile* which had been received from the Royal Botanical Gardens, Kew, England, has been examined. A specimen of *C. simile*, received from S. J. Hughes, IMI 7117, (DAOM 24624), collected on mouse dung, Cardiff, Wales, has also been examined. *C. simile* has not been found on seed.

CHAETOMIUM SPHAERALE Chivers, Proc. Am. Acad. Arts & Sci. 48 : 84. 1912. (Plate XI, Fig. 10)

Plants obscured by loose mass of golden-yellow hairs.

Perithecia opaque, ovoid, rounded at base, narrowed above at the ostiole, 225-275 × 225-260μ. *Terminal hairs* light-colored, smooth, closely septate, tending to break at the septa, straight below, about 4μ wide at base, becoming much branched above with long, narrow, septate, irregularly sinuous, often collapsed branches, somewhat constricted at the septa, interwoven and extending beyond the spore mass. *Lateral hairs* light-colored, smooth, septate, unbranched, straight or flexed, tapering to long, collapsed tip. *Spores* dark-colored, globose-ovoid, prominently umbonate at both ends, 6.0-7.5 × 5.0-6.0μ.

C. sphaerale resembles *C. globosum* but differs in having narrow, frequently branched terminal hairs and the perithecium narrowed above.

The type of *C. sphaerale* in the Farlow Herbarium, from caterpillars, Reading, Mass., (DAOM 24963), has been examined. The following specimens in the Chivers Herbarium, Cornell, have also been examined: No. 28-1, on old padding paper, Amesbury, Mass., 27. X. 1904, (DAOM 35547); No. 28-2, paper, Amesbury, Mass., 27. X. 1904, (DAOM 35548); No. 28-3, mouse and rat dung, Amesbury, Mass., 27. X. 1904 (DAOM 35549); No. 28-11, dung, Amesbury, Mass., 10. XI. 1904 (DAOM 35550); No. 28-13, caterpillars, Reading, Mass., 1910, (DAOM 35551) (undoubtedly from the type collection). A collection, identified as *C. sphaerale*, No. 28-14, pig dung, Marguerita, Venezuela, 1904, is probably *C. subspirale* (DAOM 35552).

CHAETOMIUM SPINOSUM Chivers, Proc. Am. Acad. Arts & Sci. 48 : 86. 1912. (Plate I, Figs. 1-4; Plate X, Fig. 9)

Plants brown, distinct, upright, with straight, golden-yellow hairs.

Perithecia opaque, ovoid, 300-320 × 240-250μ. *Terminal hairs* of two kinds, (*a*) primary terminal hairs dark-colored and coarsely roughened below, fading and smooth above, 7μ wide at base, straight, unbranched, rigid, spinelike, tapering rapidly to a short, collapsed tip, extending beyond the spore mass, (*b*) secondary terminal hairs light-colored, finely roughened, septate, constricted at the septa, straight, untapered, narrow, repeatedly branched at right angles and rebranching, basal cell rounded at point of attachment. *Lateral hairs* spinelike, unbranched, similar to primary terminal hairs. *Spores* dark-colored, small, egg-shaped, rounded at both ends, 5.0-6.0 × 3.0-3.5μ, extruded in cirrhi.

The spinelike primary terminal hairs, septate, constricted secondary hairs with right-angled branching, and the small, egg-shaped spores distinguish *C. spinosum*.

The type isolation of *C. spinosum* from rat dung, Buenos Aires, Argentina, in the Farlow Herbarium, (DAOM 24964), has been examined. A second collection, probably from the type, in the Chivers Herbarium, No. 7-1, from

rat dung, Buenos Aires, 1907, (DAOM 35565), has also been examined and found to be a mixed collection, containing also perithecia of *C. cochliodes*. Recently, an isolation from oat seed, County Down, Northern Ireland, –. III. 1950, has been received (DAOM 35566).

CHAETOMIUM SPIRALE Zopf, Nova Acta Leop. Carol. Akad. 42 : 275. 1881.
(Plate VI, Figs. 4-6; Plate XII, Fig. 7)

"Dark brown to black. Perithecia of medium size 150-300μ, globose to ovate. . . ." (4). 245 × 185-210μ. *Terminal hairs* uniformly spirally coiled with as many as 14 coils, dark-colored, roughened, septate, of uniform diameter, about 5μ wide. *Lateral hairs* dark-colored, finely roughened, septate, 3.5μ wide at base, slightly flexed, ending in rounded tip. *Spores* dark-colored, ovoid, faintly apiculate at both ends, 9.0-11.0 × 7.5-9.0μ.

C. spirale differs from *C. bostrychodes* in having longer spirally coiled hairs and larger spores, and from *C. aterrimum* in having narrower hairs and larger spores.

C. spirale has not been isolated from seed but slide No. 3385 in the Farlow Herbarium, received from F. J. Seaver by A. H. Chivers July, 1913, of *C. spirochaete* Palliser (syn. *C. spirale*) has been examined. Ames' specimen, No. 1043.8, in the Farlow Herbarium labelled *C. aterrimum* was found to be typical of *C. spirale* (DAOM 35567).

CHAETOMIUM SUBSPIRALE Chivers, Proc. Am. Acad. Arts & Sci. 48 : 84. 1912.
(Plate XIII, Fig. 5)

Plants brown, erect, with white hairs and brown, irregular spore mass.

Perithecia opaque, barrel-shaped to ellipsoid, 385-400 × 250-290μ. *Terminal hairs* dark-colored, smooth, closely and distinctly septate, about 4μ wide at base, straight below, fading, tapering only slightly, and spirally coiled above with up to 12 narrow coils, increasingly distant. *Lateral hairs* light-colored, smooth, septate, 3.5μ wide, straight, tapering slightly to three- to four-coiled tip, short, about 50μ long. *Spores* dark-colored, broadly ovoid, apiculate at both ends, 5.5-6.5 × 4.5-5.5μ.

The elongate, barrel-shaped perithecium, the extended, narrow coils of the terminal hairs and the coiled tips of the short lateral hairs distinguish *C. subspirale*.

The type of *C. subspirale* in the Farlow Herbarium, labelled "pure culture on cow dung from original collection, A. H. C." has been examined (DAOM 24965) but intact perithecia could not be obtained. However, a number of specimens of *C. subspirale* in the Chivers Herbarium, Cornell, have been seen, as follows: No. 27-1, dung, shipboard, 9. XII. 1903; No. 27-2, dung, Middlesex Falls, Mass., 4. II. 1905; No. 27-3, paper, Cambridge, Mass., 24. XI. 1904, (DAOM 35568); No. 27-5, dung, Cambridge, Mass., –. I. 1907; No. 27-6, sheep dung, Randolph, N. H., 28. II. 1904; No. 27-7, porcupine dung, Randolph, N. H., 28. II. 1904; No. 27-8, pig dung,

Marguerita, Venezuela; No. 27-9, horse dung, Cambridge, Mass., 1905; No. 27-10, dog dung, Cambridge, Mass., 1905; No. 27-11, muskrat dung, Cambridge, Mass., 1905; No. 27-12, rat dung, Isles of Shoals, N. H., 1906; No. 27-13, goose dung, Waverley, Mass., –. III. 1910, (DAOM 35569); No. 27-14, deer dung, Corbin Park, N. H., 28. X. 1909, (DAOM 35570); No. 27-19, hen dung, South America, 4. XII. 1903, (DAOM 35571). A culture from litter, Douglas Lake, Mich., received from G. W. Martin, No. 6381, has been identified as *C. subspirale* (DAOM 24192).

CHAETOMIUM SUCCINEUM Ames, Mycologia, 41 : 645. 1949.

(Plate I, Figs. 5-8; Plate XI, Fig. 9)

Plants brown with loose, gray to brown hairs.

Perithecia opaque, globose, about 260μ in diameter. *Terminal hairs* slender, 2-3μ wide, dark-colored, smooth or minutely roughened, septate, untapered, straight or flexed below, terminating in two to three large looping coils or up to seven sinuous, distant coils. *Lateral hairs* similar but not coiled, ending in a hyaline, sharp tip. *Spores* dark-colored, ellipsoid, rounded at both ends, 12-15-(18) × 7.5-8.5-(10.0)μ.

C. succineum is characterized by the slender, coiled terminal hairs and large ellipsoid spores. It differs from *C. globosum* which has lemon-shaped spores and from *C. murorum* which has stout, circinate terminal hairs.

C. succineum has been isolated from seeds of the following: crested wheat grass (*Agropyron cristatum* J. Gaertn.) from Saskatchewan (DAOM 35572); celery (*Apium graveolens* L. var. *dulce* DC.) from California (DAOM 7420); beets (*Beta vulgaris* L.) from California (DAOM 15721); parsley (*Petroselinum hortense* Hoffm.) from California (DAOM 7421); and peas (*Pisum sativum* L.) from Alberta (DAOM 14206 and 20080).

A specimen of *C. succineum* was received from Ames, J-6259 and J-6260 (DAOM 24182) and a culture from G. W. Martin, 6259, from Shasta fir, Mt. Shasta, Cal. (DAOM 24174) probably from the same original collection.

CHAETOMIUM TETRASPORUM Hughes, Trans. Brit. Mycol. Soc. 29 : 72. 1946.

(Plate XI, Fig. 12)

Plants gray to gray-brown with close mass of hairs.

Perithecia subglobose, opague, 300-450μ in diameter. *Terminal hairs* dark-colored, finely roughened to smooth, septate, 5μ wide below, loosely coiled, branched, with ultimate branches narrow, loosely coiled with up to eight coils. *Lateral hairs* light-colored, finely roughened, septate, straight or slightly flexed, long. *Spores* dark-colored, variable in shape, mostly unevenly lemon-shaped, prominently umbonate at both ends, others unequally rectangular, 10.0-14.0 × 7.0-9.0μ.

C. tetrasporum may be distinguished by the much branched, spirally coiled terminal hairs and the large, irregular, lemon-shaped to rectangular spores.

A specimen from the type isolation of *C. tetrasporum*, IMI 5639, from S. J. Hughes has been examined (DAOM 24578).

CHAETOMIUM THERMOPHILE La Touche, Trans. Brit. Mycol. Soc. 33 : 95. 1950.

(Plate X, Fig. 4)

Perithecia globose to subglobose, small, about 125μ in diameter, translucent. *Terminal hairs* light-colored, roughened, septation obscure, extremely uneven with irregular constrictions, about 3.5μ wide, irregularly and repeatedly dichotomously branched at wide angles and ending in a sharp tip. *Lateral hairs* similar. *Spores* dark-colored, globose to ovoid, prominently umbonate on one end, 7.5-9.5 × 6.5-8.5μ.

C. thermophile may be distinguished by its uneven, dichotomously branched hairs and its large, subglobose spores, prominently umbonate on only one end. The cylindrical, monostichous asci could not be discerned.

C. thermophile is known only from the type which was isolated from fermenting straw in a mushroom bed compost in England. A culture was kindly provided by C. J. La Touche and a slide from the type collection, IMI 39719, was received from S. J. Hughes (DAOM 24625).

CHAETOMIUM TORTILE Bainier, Bull. Trimest. Soc. Myc. France, 25 : 214-215. 1909.

(Plate XIII, Fig. 8)

Plants obscured by profuse, widespreading, grayish-brown mass of hairs.

Perithecia opaque, subglobose, sometimes wider than tall, about 260μ in diameter. *Terminal hairs* dark-colored, coarsely roughened, septate, about 7μ wide, straight to undulate below, above consisting of a series of close, spiral coils in reversed direction, each series of coils having four to six coils, often not in line with the axis of the hair and giving a contorted or tortuous appearance, ending in a blunt, circinate tip. *Lateral hairs* light-colored, finely roughened, septate, 3-4μ wide, undulate, ending in a long collapsed tip. *Spores* dark-colored, broadly ovoid, subapiculate at one or both ends, 6.5-8.0 × 5.5-6.5μ.

The series of reversed, close coils in *C. tortile* distinguish this species from all others.

C. tortile has not been isolated from seed. A specimen in the Farlow Herbarium, "on sphagnum running from culture of rabbit dung, Hanover, N. H.", identified by Chivers, (DAOM 35573), has been examined. Two collections in the Chivers Herbarium, Cornell, No. 11-1, (DAOM 35574), and No. 11-2 (DAOM 35623), both on rabbit dung, Hanover, N. H., 1905, have also been seen. A specimen of *C. tortile* has also been received from S. J. Hughes, ex herb. IMI 38776, isolated from old fox dung, Oxford, England, 15. IX. 1949, (DAOM 24627).

The spore dimensions, given above, were determined from the Farlow specimen (DAOM 35573), identified by Chivers, and the Cornell specimen, Chivers No. 11-1 (DAOM 35574), and are somewhat smaller than the dimensions, 7.3-11.3 × 6.4-9μ, in Chivers' description (4). However,

Chivers stated that the spores are extremely variable in size. Bainier (3) also mentioned that the shape and dimensions are extremely irregular but that the oval spores, apiculate at both ends and measuring 8 × 6μ, are the most numerous, thus, smaller than the average given by Chivers, 9 × 7.6μ.

CHAETOMIUM TORULOSUM Bainier, Bull. Trimest. Soc. Myc. France, 25 : 224-226. 1909.

(Plate XIII, Fig. 4)

Plants brown, erect, distinct, with sparse, short, golden hairs, overtopped by brown spore mass, spores occasionally in cirrhi.

Perithecia opaque when mature, elongate, vase-shaped, 400-485 × 225-240μ. *Terminal hairs* light-colored, smooth, septate, often breaking at the septa, 3.5μ wide at base, becoming irregularly flexed above, constricted at the septa, ending in a collapsed, contorted tip. *Lateral hairs* light-colored, smooth, septate, alternate cells collapsed, 3.5-5.0μ wide at base, short, straight or curved slightly, ending in a short, collapsed tip. *Spores* dark-colored, broadly ovoid, umbonate at both ends, 6.0-7.5 × 5.0-6.0μ.

The large, vase-shaped perithecia, long, flexed terminal hairs, and the lemon-shaped spores distinguish *C. torulosum* from *C. seminudum* which it resembles most closely.

C. torulosum has not been isolated from seed but the following collections have been seen; in the Farlow Herbarium, on culture of old paper, Cambridge, Mass., 5. XII. 1903, (DAOM 24967); in the Chivers Herbarium, Cornell, No. 5-1, on paper, Cambridge, Mass., 3. II. 1905, (DAOM 35624); No. 5-2, on rabbit dung, Cambridge, Mass., 1899, (DAOM 35625); No. 5-3, on mouse dung, Cambridge, Mass., 1905; No. 5-5, on guinea pig dung, Hanover, N. H., 1904; No. 5-7, on dead grass, Hanover, N. H., 1904; No. 5-8, on canes, Jarva, 1905; No. 5-9, on corn husks, Hanover, N. H., 1906; No. 5-10, on squash, Cambridge, Mass., 1903; No. 5-11, on barrel hoop, Amesbury, Mass., 1905; No. 5-12, on paper, Amesbury, Mass., 1904; and No. 5-13, on grouse dung, Cohasset, Mass., 29. III. 1905.

CHAETOMIUM TRIGONOSPORUM (Marchal) Chivers, Mem. Torrey Botan. Club, 14 : 166. 1915.

(Plate X, Fig. 12)

Plants brown to black, erect, distinct, with sparse, brown, terminal hairs, and long straight cirrhi of spores.

Perithecia opaque, ovoid, narrowed at the ostiole, "250-340 × 160-262μ" (4). Terminal hairs dark-colored below, fading above, smooth, septate, 4.5-5.0μ wide at base, straight, long, ending in rounded tip. *Lateral hairs* similar but short, 2.5μ wide at base, basal cell inflated. *Spores* dark-colored, distinctly triangular in face view, 6.5-8.5 × 3.5-5.5μ.

C. trigonosporum is distinctive in its straight, unbranched hairs and its triangular spores.

This species has not been isolated from seed but specimens in the Farlow Herbarium, labelled "pure culture on rabbit dung from original collection of rabbit dung from North Carolina, A. H. C." (DAOM 24968), and in Chivers Herbarium, No. 6-1, rabbit dung, Cambridge, Mass., 1908, (DAOM 35626), and No. 6-2, rabbit dung, Cambridge, Mass., 1912, (DAOM 35628), have been seen.

CHAETOMIUM TRILATERALE Chivers, Proc. Am. Acad. Arts & Sci. 48 : 87-88. 1912.

Chaetomium cupreum Ames, Mycologia, 41 : 642-643. 1949.

(Plate IV, Figs. 5-8; Plate XI, Fig. 6)

Plants olive-yellow, copper, to brown.

Perithecia translucent, becoming opaque with age, globose to ovoid, 125-135 × 120-125μ, with simple wide ostiole. *Terminal hairs* dark-colored below, fading above, finely roughened, septate, 5-6μ wide at the middle, arcuate from the base and usually incurved, ending in a two-to-three-spiral convolute tip, coils of diminishing diameter. *Lateral hairs* similar but narrower, 2.5-3.5μ wide at base, light-colored, and loosely, one-to-two-spiral convolute at tip. *Spores* dark-colored, hemi-ovoid, or unevenly ovoid, flattened on one side, 8.5-9.5 × 5.0-6.0μ.

The arcuate terminal hairs with one-to-three-coiled tips and the ovoid spores, flattened on one side, distinguish *C. trilaterale* from *C. aureum* in which the terminal hairs have incurved or once-recurved tips and the spores are ellipsoid-flattened; from *C. fusiforme* in which the spores are fusiform; and from *C. turgidopilosum* in which the hairs are inflated and the spores are lemon-shaped.

In addition to the type in the Farlow Herbarium (DAOM 24969), a number of other collections of *C. trilaterale* have been examined. A specimen from acorns, Ithaca, N.Y., herbarium of W. L. White, No. 1595, in the Farlow Herbarium is representative (DAOM 35627). A collection in Chivers Herbarium, Cornell, No. 2 from paper, Cambridge, Mass., 1904-05, is probably from the type material (DAOM 35629). Two cultures of *C. trilaterale*, received from the Muséum d'Histoire Naturelle, Paris, No. 517, (DAOM 35630), and No. 593 (DAOM 35631) are typical.

Recently, Ames (1) described *Chaetomium cupreum*, separating it mainly on the bright copper color of the hairs. Comparison of a specimen of *C. cupreum* from Ames (DAOM 24187) with the type of *C. trilaterale* shows that it is very close, especially in its one-to-three-convolute tips of both terminal and lateral hairs. However, it differs from *C. trilaterale* in having a slightly longer spore, 9.0-12.5 × 5.0-6.0μ. The spores of *C. cupreum* are thus very similar to those of *C. aureum* (8.5-11.0 × 4.5-5.5μ). Similarly, a specimen on apple wood, from Iowa City, Iowa, G. W. Martin No. 6408, (DAOM 35632), which agrees with *C. trilaterale* in other respects, has an ellipsoid, only slightly flattened, smaller spore, 7.0-8.5 × 4.0-5.5μ. Undoubtedly, differences in

such a character as spore shape and size would warrant separation of *C. cupreum* and Martin's specimen from *C. trilaterale* but whether they should be given species or variety rank is open to question. We prefer to retain them under *C. trilaterale* until a more complete study of intergrading forms can be made.

CHAETOMIUM TURGIDOPILOSUM Ames, Mycologia, 41 : 639. 1949.

(Plate IV, Figs. 12-14; Plate XI, Fig. 4)

Plants dark brown to black with brown hairs and gray-brown mycelium.

Perithecia opaque, ovoid, small, 125-140 × 105-120μ, with wide, simple ostiole. *Terminal hairs* dark-colored, fading above, smooth, septate, 7-7.5μ at inflated middle portion, narrower above and at base, arcuate with incurved or once-recurved, blunt tip. *Lateral hairs* light-colored, smooth, septate, narrow, about 3μ wide at base, straight below, irregularly flexed above, with long, pointed, hyaline tip. *Spores* dark-colored when mature, ovoid and umbonate at both ends, lemon-shaped, 7.5-9.5 × 5.5-7.0μ.

The inflated, arcuate terminal hairs with once-recurved tips and the lemon-shaped spores distinguish *C. turgidopilosum* from the related species, *C. aureum*, *C. trilaterale*, and *C. fusiforme*.

C. turgidopilosum has not been isolated from seed but a culture received from Ames, J-730, presumably from the type isolation, has been examined (DAOM 24580).

Uncertain Species

Ames (2) has recently described three species of *Chaetomium*, *C. fibripilium*, *C. mollipilium*, and *C. nigricolor*, but as it has not been possible to examine specimens of these species, they are not included above.

Garbowski (5) described *Chaetomium tortuosum* in 1936 and a culture under this name, listed as from Garbowski, was received from the Centraalbureau voor Schimmelcultures, Baarn, but as no mature perithecia could be obtained, it is only mentioned here.

Chaetomium fiscicolum Petrak (9) is not a *Chaetomium* but a species of *Sordaria*, according to S. J. Hughes, *in litt.*

Acknowledgments

The authors wish to acknowledge their indebtedness to Dr. L. M. Ames, Dr. G. W. Martin, Mr. J. A. Stevenson, Dr. R. Heim, Mr. C. J. La Touche, Prof. A. C. Batista, and others who have provided us with specimens and cultures, and especially to Mr. S. J. Hughes who has made available many of the types in the herbarium of Commonwealth Mycological Institute, for his opinions on a number of controversial species, and for reviewing the manuscript. We are also indebted to the late Dr. D. H. Linder and Dr. Richard P. Korf for permission to examine specimens in the Farlow and Cornell herbaria, to Dr. B. Boivin for the Latin description, and to Miss M. E. Elliott and Mrs. A. M. Floyd for technical assistance.

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PLATE I

FIGS. 1-4. *Chaetomium spinosum* Chivers. 1. Mature perithecium. 2. Unbranched terminal hairs. 3. Branched terminal hairs. 4. Spores.
FIGS. 5-8. *Chaetomium succineum* Ames. 5. Mature perithecium. 6. Terminal hairs. 7. Spores. 8. Ascus.

PLATE II

FIGS. 1-4. *Chaetomium seminudum* Ames. 1. Mature perithecia. 2. Ostiolar region of the perithecium. 3. Spores. 4. Young ascus.
FIGS. 5-7. *Chaetomium cristatum* Ames. 5. Young perithecium. 6. Terminal hairs. 7. Young ascus and mature spores.
FIGS. 8-10. *Chaetomium ampullare* Chivers. 8. Perithecium. 9. Terminal hairs. 10. Spores.

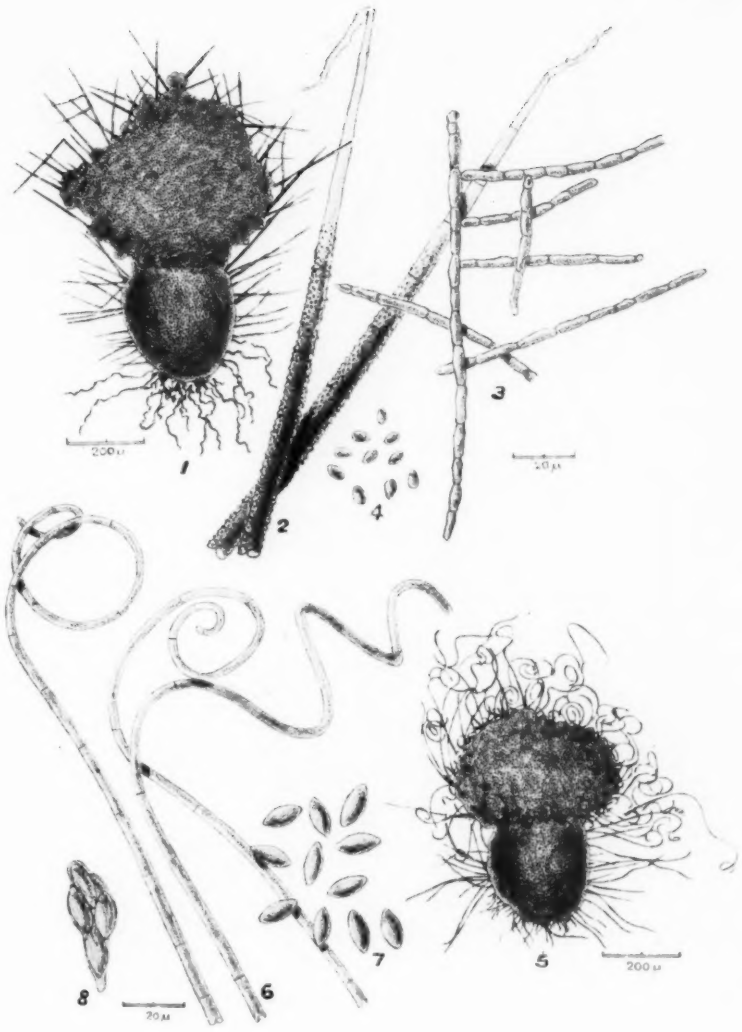
PLATE III

FIGS. 1-4. *Chaetomium murorum* Corda. 1. Perithecia. 2. Terminal hairs. 3. Spores. 4. Ascus.
FIGS. 5-7. *Chaetomium circinatum* Chivers. 5. Perithecium. 6. Terminal hairs. 7. Spores.

PLATE IV

FIGS. 1-4. *Chaetomium aureum* Chivers. 1. Perithecium. 2. Terminal hairs. 3. Spores. 4. Ascus.
FIGS. 5-8. *Chaetomium trilaterale* Chivers. 5. Perithecium. 6. Terminal hairs. 7. Spores. 8. Asci.
FIGS. 9-11. *Chaetomium fusiforme* Chivers. 9. Perithecium. 10. Terminal hairs. 11. Spores and ascus.
FIGS. 12-14. *Chaetomium turgidopilosum* Ames. 12. Perithecium. 13. Terminal hairs. 14. Spores.

PLATE I



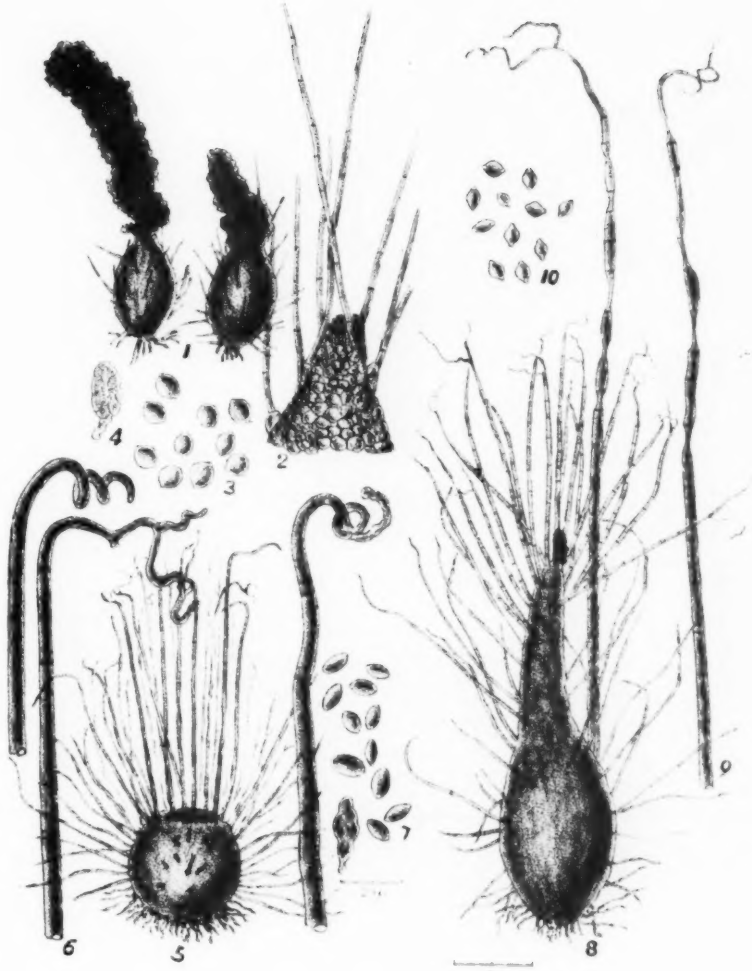

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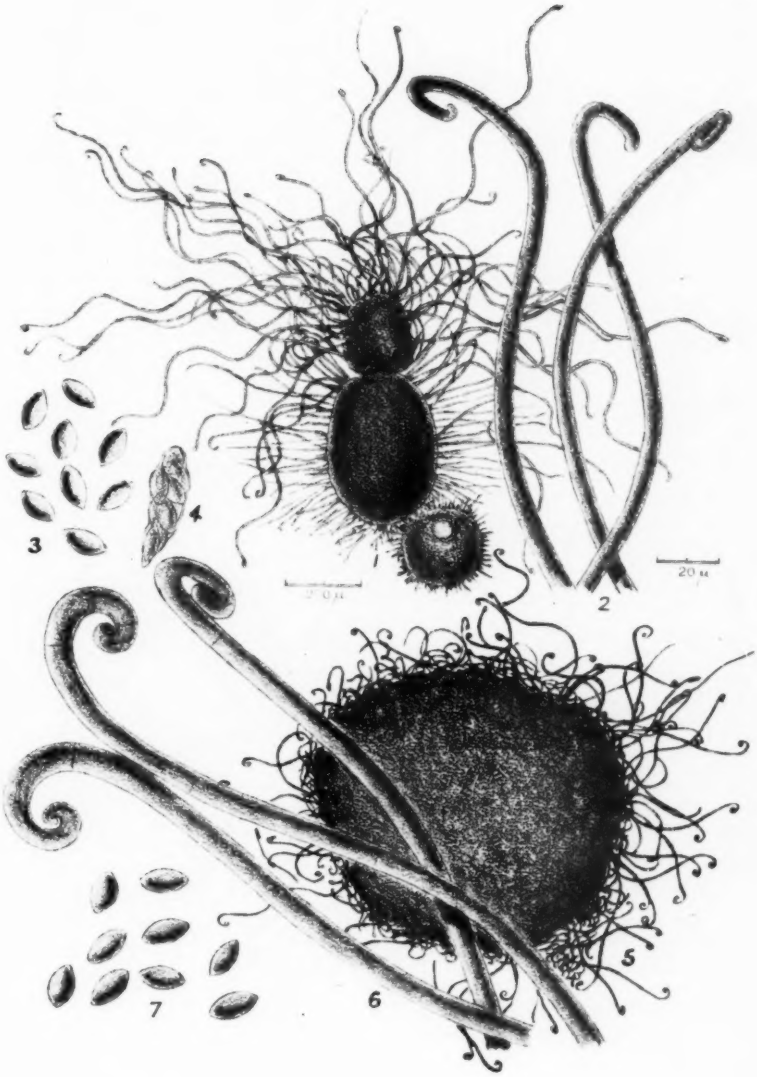
PLATE III



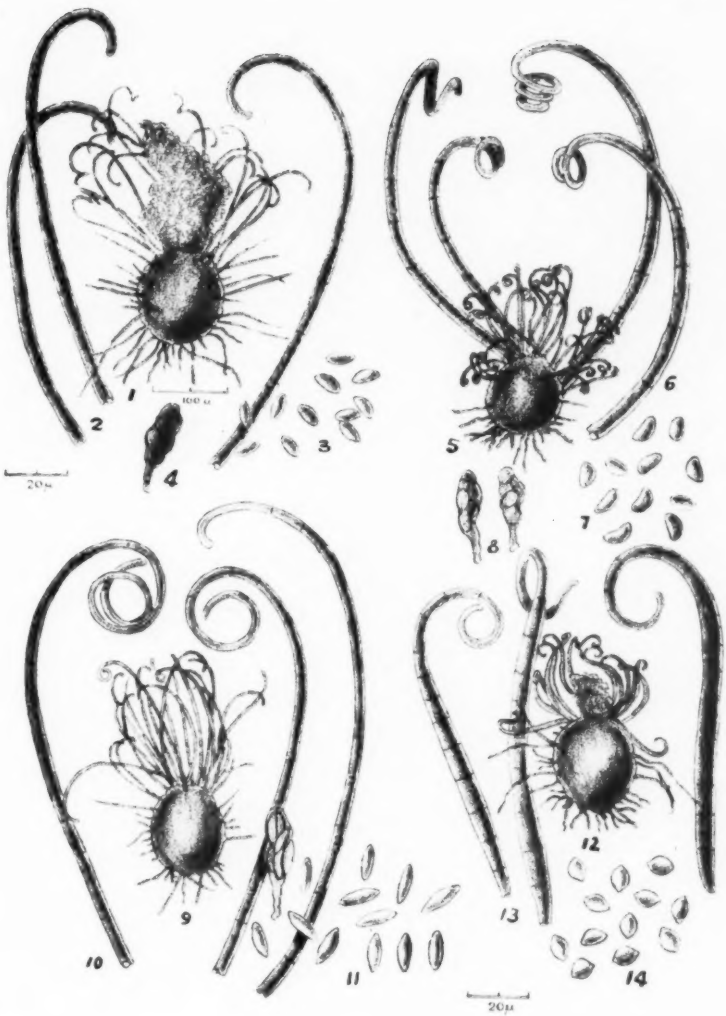

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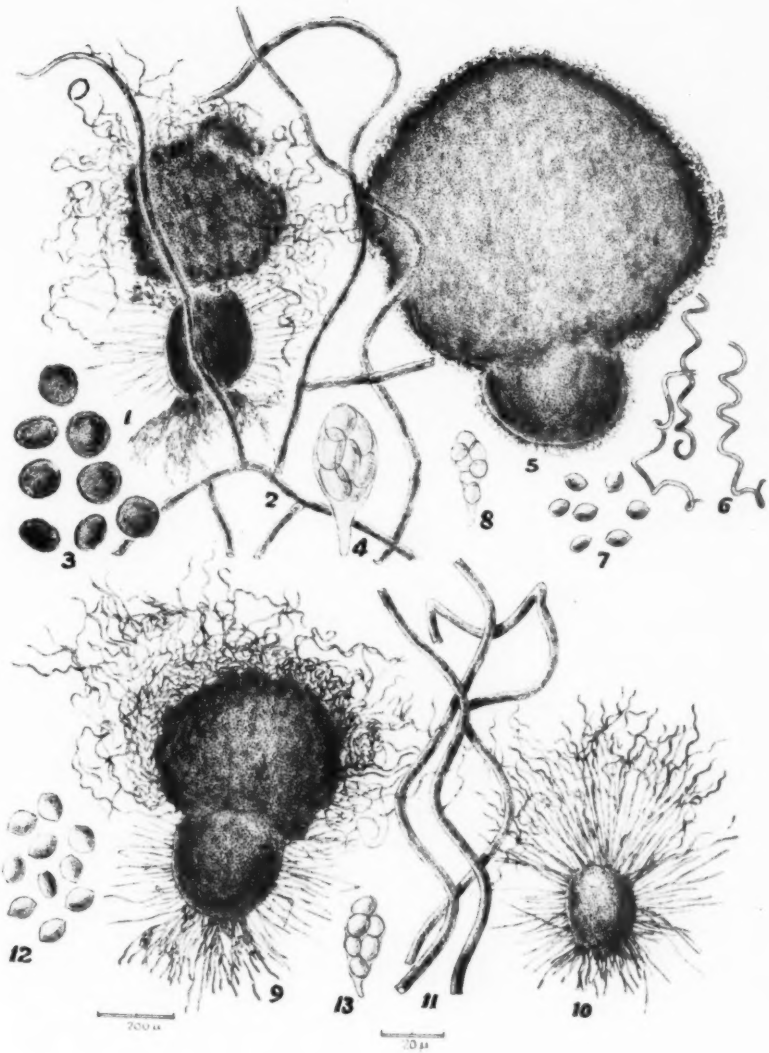
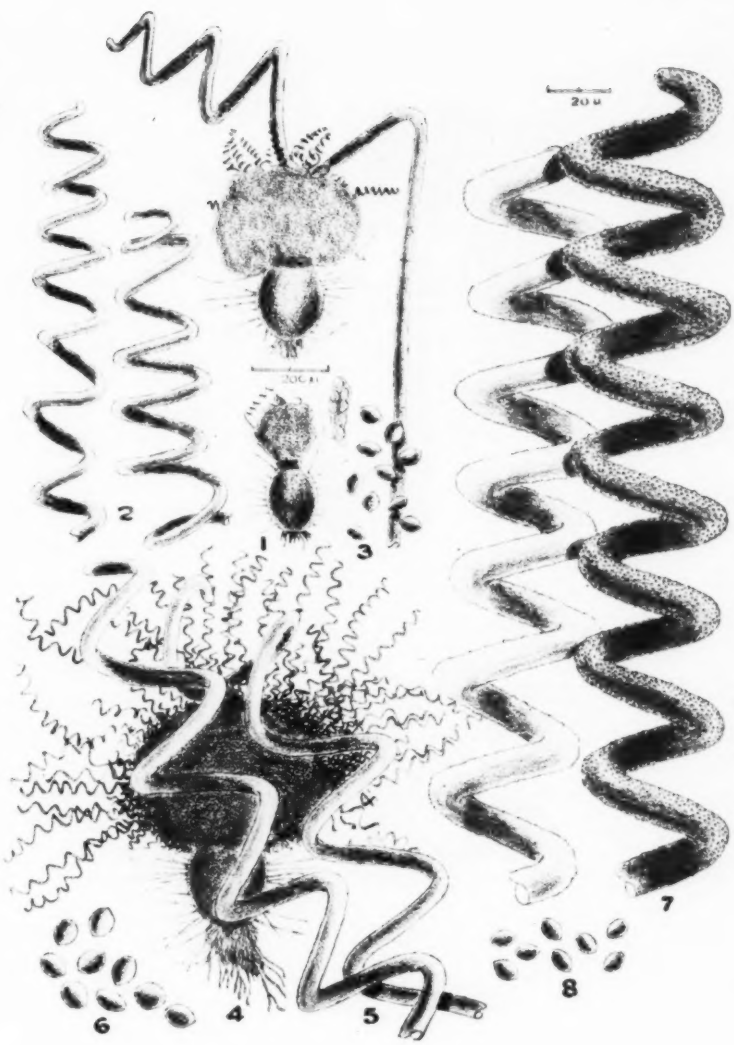
PLATE V

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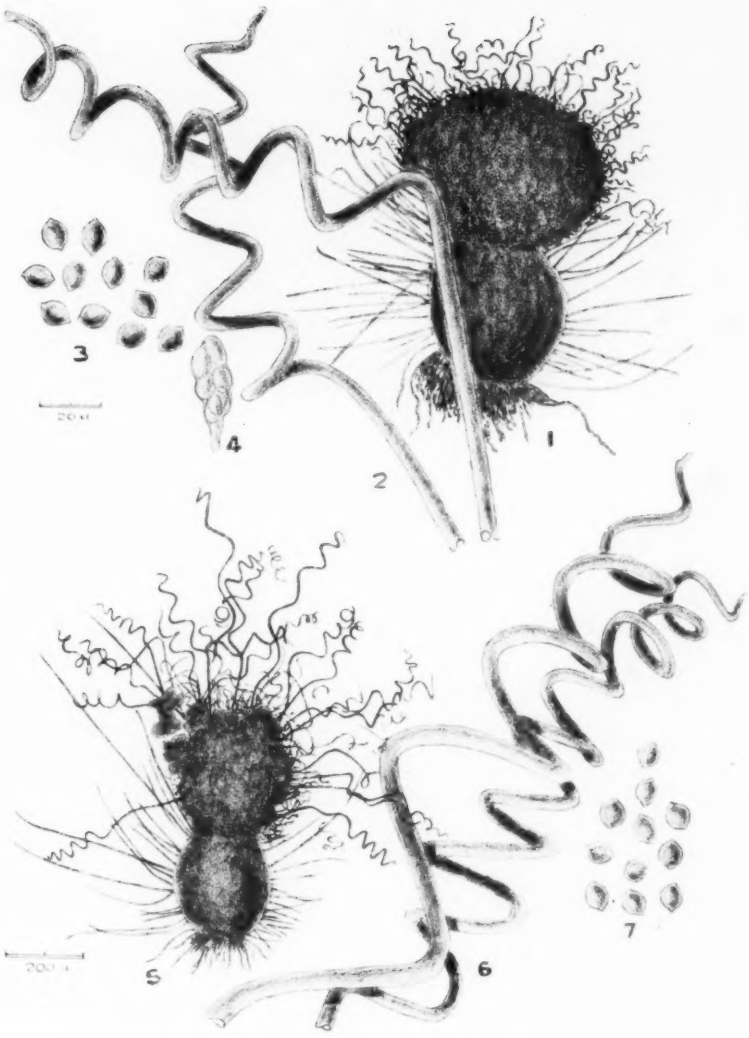
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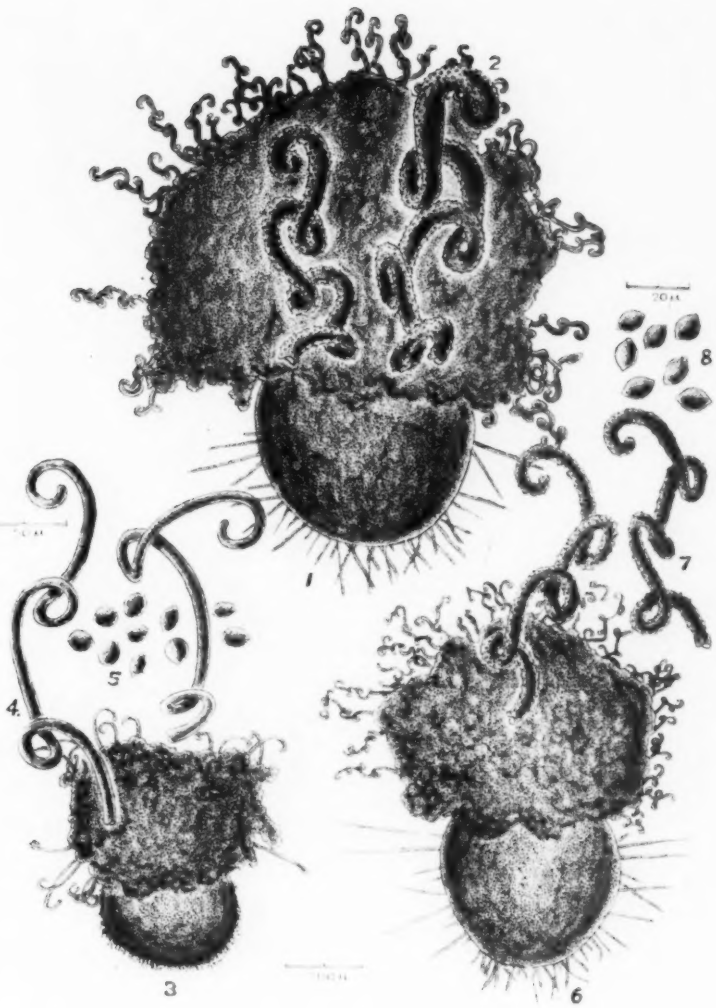
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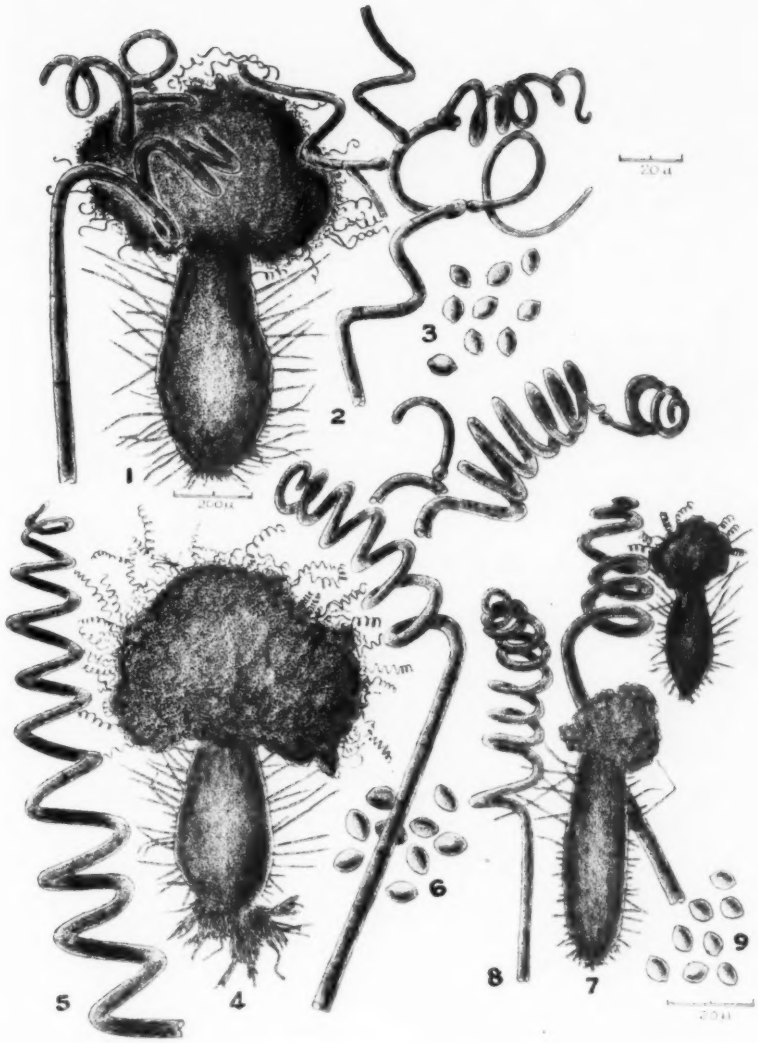
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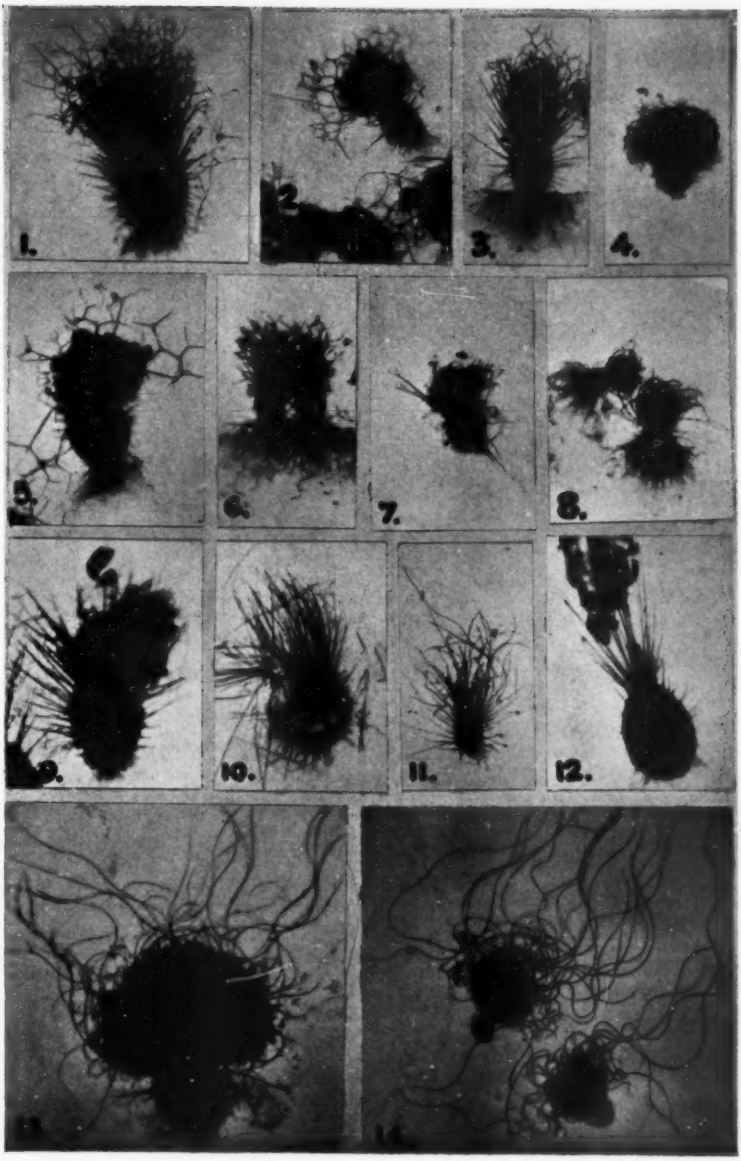
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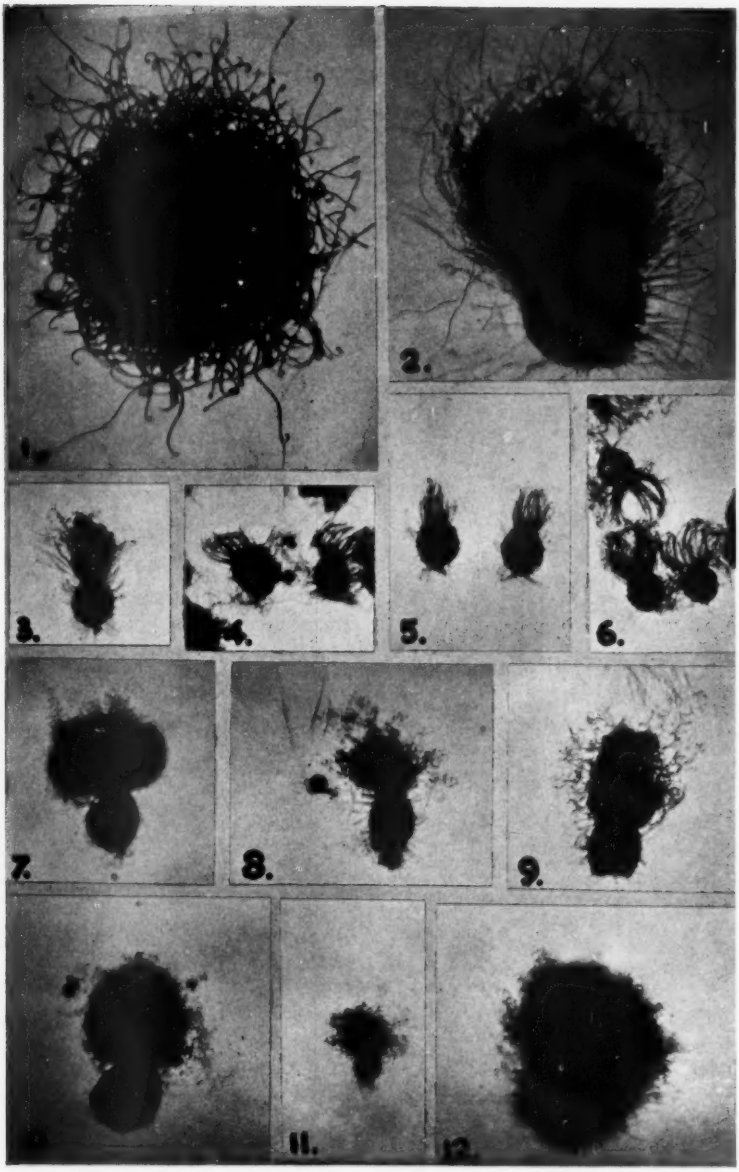
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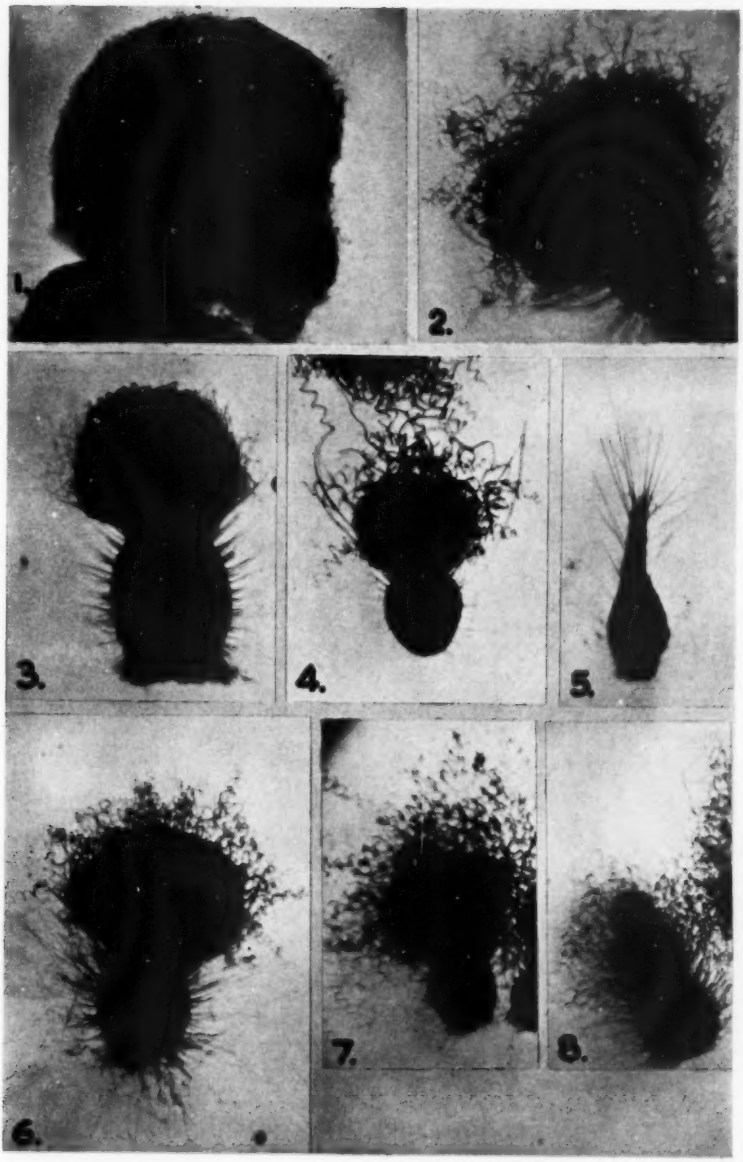
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PLATE XIII

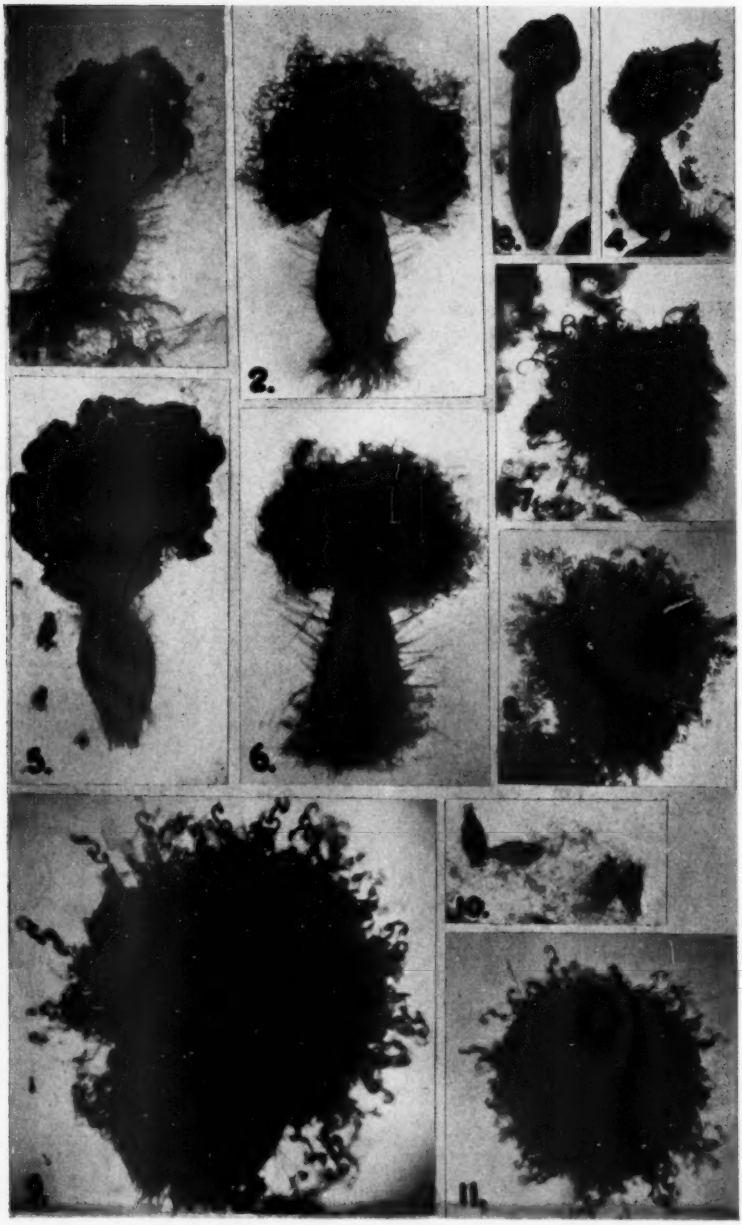

PLATE V

FIGS. 1-4. *Chaetomium atrosporum* n. sp. 1. Perithecium. 2. Terminal hairs. 3. Spores. 4. Ascus.
FIGS. 5-8. *Chaetomium ochraceum* Tschudy. 5. Perithecium. 6. Terminal hairs. 7. Spores. 8. Ascus.
FIGS. 9-13. *Chaetomium globosum* Kunze. 9. Mature perithecium. 10. Young perithecium. 11. Terminal hairs. 12. Spores. 13. Ascus.

PLATE VI

FIGS. 1-3. *Chaetomium bostrychodes* Zopf. 1. Perithecium. 2. Terminal hairs. 3. Spores and ascus.
FIGS. 4-6. *Chaetomium spirale* Zopf. 4. Perithecium. 5. Terminal hairs. 6. Spores.
FIGS. 7-8. *Chaetomium aterrimum* Ellis & Everhart. 7. Terminal hairs. 8. Spores.

PLATE VII

FIGS. 1-4. *Chaetomium cochliodes* Palliser. 1. Perithecium. 2. Terminal hairs. 3. Spores. 4. Ascus.
FIGS. 5-7. *Chaetomium angustum* Chivers. 5. Perithecium. 6. Terminal hairs. 7. Spores.

PLATE VIII

FIGS. 1-2. *Chaetomium contortum* Peck. 1. Perithecium. 2. Terminal hairs.
FIGS. 3-5. *Chaetomium simile* Massee & Salmon. 3. Perithecium. 4. Terminal hairs. 5. Spores.
FIGS. 6-8. *Chaetomium crispatum* Fuckel. 6. Perithecium. 7. Terminal hairs. 8. Spores.

PLATE IX

FIGS. 1-3. *Chaetomium caprinum* Bainier. 1. Perithecium. 2. Terminal hairs. 3. Spores.
FIGS. 4-6. *Chaetomium pachypodioides* Ames. 4. Perithecium. 5. Terminal hairs. 6. Spores.
FIGS. 7-9. *Chaetomium microcephalum* Ames. 7. Perithecia. 8 Terminal hairs. 9. Spores.

PLATE X

Photomicrographs of perithecia of *Chaetomium* spp. (× 50).

FIGS. 1. *Chaetomium elatum*. 2. *C. dolichotrichum*.
3. *C. funicola*. 4. *C. thermophile*. 5. *C. indicum*.
6. *C. erectum*. 7. *C. cancroideum*. 8. *C. reflexum*.
9. *C. spinosum*. 10. *C. cristatum*. 11. *C. atrobrunneum*.
12. *C. trigonosporum*. 13. *C. murorum*. 14. *C. causiaeformis*.

PLATE XI

Photomicrographs of perithecia of *Chaetomium* spp. (× 50).

FIGS. 1. *Chaetomium circinatum*. 2. *C. olivaceum*. 3. *C. aureum*.
4. *C. turgidopilosum*. 5. *C. fusiforme*. 6. *C. trilaterale*.
7. *C. bostrychodes*. 8. *C. gangligerum*. 9. *C. succineum*.
10. *C. sphaerale*. 11. *C. brasiliense*. 12. *C. tetrasporum*.

PLATE XII

Photomicrographs of perithecia of *Chaetomium* spp. (× 50).

FIGS. 1. *Chaetomium ochraceum*. 2. *C. angustum*. 3. *C. quadrangulatum*.
4. *C. convolutum*. 5. *C. ampullare*. 6. *C. cochliodes*.
7. *C. spirale*. 8. *C. globosum*.

PLATE XIII

Photomicrographs of perithecia of *Chaetomium* spp. (× 50).

FIGS. 1. *Chaetomium atrosporum*. 2. *C. caprinum*.
3. *C. microcephalum*. 4. *C. torulosum*. 5. *C. subspirale*.
6. *C. pachypodioides*. 7. *C. simile*. 8. *C. tortile*.
9. *C. contortum*. 10. *C. seminudum*. 11. *C. crispatum*.

PYRENOMYCETES OF BRITISH COLUMBIA[1]

By Margaret E. Barr[2]

Abstract

The 258 species and six varieties listed from the province are distributed in 94 genera as follows: Perisporiales — 28 species and three varieties in 14 genera; Hypocreales — 19 species in 10 genera; Sphaeriales — 205 species and three varieties in 65 genera; Dothideales — six species in five genera.

The Pyrenomycetes have received very little study in the province of British Columbia. Parasitic species have been collected by plant and forest pathologists working in this region, and a few other collections have been noted, but the vast numbers of saprophytic Pyrenomycetes remain untouched. In this paper the writer attempts to bring together all references from the literature in addition to recording collections seen and identified.

The first collections noted from British Columbia were those made by John Macoun and determined by J. B. Ellis (11, 12, 13, 14) and John Dearness (9, 10). Records of plant and forest pathogens were obtained from the Canadian Plant Disease Surveys from 1920 to the present (5). Other records have been included in this list from the literature.

The writer's studies on British Columbia Pyrenomycetes are based on collections made during two years. Because a survey of the entire province was not feasible, representative areas were covered as thoroughly as possible. These areas include the campus of the University of British Columbia, Duncan and Saanichton on Vancouver Island, the open parklands of the interior plain of British Columbia between Penticton and Salmon Arm, and an alpine area, the Cathedral Lakes, in the Ashnola district in the southern part of the province. In addition to these collections the writer has examined collections from British Columbia in the Mycological Herbarium at Ottawa, with the kind permission of Dr. J. W. Groves. She has also examined collections in the Dominion Laboratories of Plant Pathology at Saanichton and Summerland, and in the Dominion Laboratory of Forest Pathology at Victoria. Inspection of plant specimens from the Phanerogamic Herbarium of the University of British Columbia yielded further collections from dead leaves and stalks and extended both region and number of hosts studied.

Determinations in most cases were made by the author; collections determined by others are so indicated. The majority of the collections are deposited in the Mycological Herbarium of the University of British Columbia and are indicated by the letters UBC, as this is an unlisted herbarium. The letters DAOM indicate collections in the Mycological Herbarium, Division of

[1] *Manuscript received June 17, 1953.*

Presented as a thesis for the master's degree at the University of British Columbia, Vancouver, B.C., in October, 1952.

[2] *Graduate student in the Department of Botany, University of Michigan, Ann Arbor, Mich.*

Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada. To facilitate reference to the annual reports of the Canadian Plant Disease Survey, the letters CPDS are employed, followed by the year of the report.

Perisporiales

Erysiphaceae

Erysiphe aggregata (Pk.) Farl. On catkins of *Alnus* sp. (N. Saanich, UBC 302).

— **cichoracearum** DC. Thirty-two collections from Okanagan and Fraser Valleys on the following hosts: *Aster* spp., *Callistephus* sp., *Chrysanthemum* sp., *Cucumis* spp., *Delphinium* sp., *Lactuca scariola*, *Oenothera* sp., *Penstemon* sp., *Phlox* sp., *Plantago major*, *Rudbeckia laciniata*, *Solanum nigrum*, *Solidago* sp., *Zinnia* sp.

— **graminis** DC. Twenty-five collections from Fraser Valley and Vancouver Island on the following hosts: *Agropyron repens*, *Avena sativa*, *Dactylis glomerata*, *Hordeum vulgare*, *Poa* sp., *Secale cereale*, *Triticum aestivum*.

— **polygoni** DC. Twenty-nine collections from Okanagan and Fraser Valleys and Vancouver Island on the following hosts: *Aquilegia formosa*, *Brassica oleracea*, *Comandra pallida*, *Delphinium* sp., *Lathyrus ochroleucus*, *Lotus denticulatus*, *Lupinus* spp., *Matthiola* sp., *Pisum sativum*, *Polygonum* spp., *Trifolium* spp.

— sp. Not seen, reported in CPDS on *Antirrhinum* sp., *Artemisia* sp., *Rhus* sp.

Microsphaera alni (Wallr.) Salm. On *Quercus garryana* (University, UBC 1799).

— **alni** (Wallr.) Salm. var. **lonicerae** (DC.) Salm. On *Lonicera* sp. (N. Saanich. UBC 768).

— **alni** (Wallr.) Salm. var. **vaccinii** (Schw.) Salm. On *Chiogenes hispidula* (Agassiz, UBC 1449).

— **diffusa** Cke. & Pk. On *Symphoricarpos albus* (common in the Fraser and Okanagan Valleys, UBC 1719, 530, 1572, 965, 1598, 964, 963).

Phyllactinia corylea (Pers.) Karst. Eighteen collections from Okanagan and Fraser Valleys and Vancouver Island on the following hosts: *Alnus* spp., *Amelanchier alnifolia*, *Cornus* spp., *Corylus* sp., *Crataegus* sp., *Holodiscus discolor*.

Podosphaera leucotricha (Ell. & Ev.) Salm. On *Pyrus malus* (Okanagan, UBC 1681, 1546, 27).

— **oxyacanthae** (DC.) de Bary. On *Prunus* spp. (common in the Okanagan, UBC 1475, 1576, 1716, 342, 957, 1592, 1636, 1704, 1884, CPDS 1938, 1940).

Sphaerotheca humuli (DC.) Burr. Nineteen collections from Vancouver Island, Fraser and Okanagan Valleys on the following hosts: *Fragaria* sp., *Geranium viscosissimum*, *Gilia linearis*, *Heuchera glabra*, *Potentilla palustris*, *Rhus glabra*, *Rubus* spp., *Shepherdia canadensis*, *Viola* spp.

— **humuli** (DC.) Burr. var. **fuliginea** (Schlecht) Salm. Eighteen collections from Okanagan Valley and Cariboo on the following hosts: *Agoseris* spp., *Bidens cernua*, *Castilleja* spp., *Coreopsis* sp., *Lactuca* spp., *Rubus* sp., *Taraxacum* spp.

— **mors-uvae** (Schw.) Berk. & Curt. On *Ribes* spp. (Okanagan, UBC 953, 274, Vancouver, UBC 1520, 1894).

— **pannosa** (Wallr.) Lev. On *Prunus* sp. (Summerland, UBC 1895); reported in CPDS on rose and nectarine.

Uncinula aceris (DC.) Sacc. On *Acer macrophyllum* (Vancouver Island, UBC 1888, 827, University, UBC 1488, 1885). This species, according to Salmon (25), is confined to Europe and Asia. The first authentic record on this continent appears in the Canadian Plant Disease Survey (1929), on *Acer*, N. Saanich.

— **circinatum** Cke. & Pk. On *Acer* sp. (Victoria, CPDS 1928).

— **necator** (Schw.) Burr. On *Parthenocissus* sp. (Summerland, UBC 1597); *Vitis* sp. (Summerland, UBC 955).

— **salicis** (DC.) Wint. On *Myrica gale* (Cowichan Lake, det. H. S. Jackson, UBC 1889); this host has not been previously recorded. On *Populus* spp. (Summerland, CPDS 1940); *Salix* spp. (Okanagan, UBC 1568, 1673, 1892, Vancouver, UBC 1450, 84).

PERISPORIACEAE

Dimerium alpinum Cooke. On *Penstemon fruticosus* (Cathedral Lakes, UBC 1981).

Dimerosporium abietis Dear. On *Abies lasiocarpa* (Cinema, UBC 1982, immature).

— **tsugae** Dear. Fifteen collections on *Tsuga heterophylla*, from Vancouver Island, Queen Charlotte Islands, and Revelstoke.

Petriella asymmetrica Curzi. From seeds of *Beta vulgaris* (Armstrong, det. E. W. Mason, DAOM 14924); *Cucumis melo* (Armstrong, det. J. W. Groves, DAOM 14922); *Raphanus sativus* (Grand Forks, det. J. W. Groves, DAOM 14923).

Phaeocryptopus gaumannii (Rohde) Petrak. Fifteen collections on *Pseudotsuga taxifolia* from Fraser Valley and Vancouver Island.

MICROTHYRIACEAE

Asterella gaultheriae (Curt.) Sacc. On *Gaultheria shallon* (Crofton, UBC 1985).

— **hellebori** Rehm. On *Astragalus macounii* (Cathedral Lakes, UBC 2007). No *Asterella* has been described on *Astragalus*; the species description fits this collection.

Asterina rubicola Ell. & Ev. On leaves of *Rubus* sp. (Summerland, DAOM 3366, CPDS 1933).

Microthyrium arcticum Oudem. On *Potentilla flabellifolia* (Cathedral Lakes, UBC 1999); *Sibbaldia procumbens* (Garibaldi, UBC 2008).

Stigmatea robertiani Fr. On living leaves of *Geranium pusillum* (Cultis Lake, UBC 1975).

— **sequoiae** (Cke. & Hark.) Sacc. On living leaves of *Juniperus scopulorum* (Cariboo, UBC 1976, 1977, 1978). These collections are similar to Ellis's N.A.F. 3222, on leaves of *Libocedrus*, except that asci are up to 90 μ in length.

Hypocreales

NECTRIACEAE

Acrospermum compressum Tode. On *Draba paysonii* (Pemberton, UBC 1817). This fungus is retained in the Nectriaceae in accordance with Bisby (2) and Wehmeyer (34); its status is probably close to the Coryneliaceae (Brandriff (3)).

Creonectria coccinea (Pers.) Seaver. On bark of *Acer* spp. (Vancouver Island, DAOM 26108, 26098, UBC 1825, 1824).

— **cucurbitula** (Sacc.) Seaver. On bark of *Abies grandis* (Cowichan Lake, det. I. L. Conners, DAOM 1912, CPDS 1933).

— **mammoidea** (Phil. & Plow.) Seaver. Recorded by Ellis and Everhart (13), on bark of maple, B.C., Macoun. One collection (Hastings, DAOM 25) is probably this species and may well be part of the collection identified by Ellis.

— **pithoides** (Ell. & Ev.) Seaver. On bark of dead alder (Agassiz, DAOM 122, cotype), described by Ellis and Everhart (12), (Vancouver Island, DAOM April 18, 1915, det. J. Dearness).

— **purpurea** (L.) Seaver. Twelve collections from Vancouver Island and Fraser Valley on the following hosts: *Acer macrophyllum*, *Alnus oregona*, *Chaenomeles lagenaria*, *Choisya ternata*, *Ficus* sp., *Pyrus malus*, *Rubus* sp., *Spiraea menziesii*.

Erostrotheca multiformis Martin & Charles. On *Lathyrus* sp. (CPDS 1932); only the imperfect stage, *Cladosporium album* Dowson, noted.

Melanospora papillata Hotson. From seeds of *Phaseolus coccineus* (Vancouver, DAOM 14909); *Vicia faba* (New Westminister, DAOM 18353); determined by J. W. Groves.

— **townei** Griffiths. On herbarium specimens of *Amaranthus* sp. (Windermere, UBC 1826).

Nectria episphaeria (Tode) Fr. On *Diaporthe columbiensis*, (Hastings, DAOM 32); *Diatrype macounii* (Vancouver Island, DAOM Sept. 29, 1914, and April 8, 1915); *Eutypella stellulata* (University, UBC 1829); *Hypoxylon* sp. and *Melanconis thelebola* (Cowichan Lake, DAOM 26101, UBC 1820).

— **galligena** Bres. On apple and pear (Vancouver and Alberni, UBC 399, 26, CPDS 1926, 1931, 1935, 1939, 1946).

— **sanguinea** Fr. On *Betula* sp. (Hastings, DAOM 34).

Nectriella sp. probably **N. pedicularis** (Tracy & Earle) Seav. On *Arnica latifolia* and *Lupinus latifolius* (Cathedral Lakes, UBC 1972, 2051); *Phlox diffusa* (Garibaldi, UBC 1816). These collections are all somewhat immature and are placed provisionally in this species.

Hypocreaceae

Hypomyces aurantius (Pers.) Tul. On *Fomes pinicola* (Hope, UBC 1818); *Polyporus resinosus* (Revelstoke, UBC 1819, 1821).

— **lactifluorum** (Schw.) Tul. On *Lactarius* sp. (Savary Island, UBC 975, Hatzig, DAOM 3994).

Clavicipitaceae

Claviceps grohii Groves. In ovaries of *Carex stellulata* (Milner, DAOM 12072, type, det. J. W. Groves (17)); *Carex* aff. *festivella* (Aldergrove, DAOM 12073).

— **purpurea** Tul. Twenty-one collections from all parts of the province on the following hosts: *Agropyron cristatum, Avena sativa, Bromus inermis, Calamagrostis canadensis, Elymus* spp., *Festuca elatior, Hordeum vulgare, Lolium perenne, Phleum pratense, Secale cereale, Triticum aestivum.*

Cordyceps myrmecophila Ces. On ants (Vancouver, Mains (19)).

Epichloe typhina (Pers.) Tul. On *Holcus lanatus* (University, UBC 1823). Mature stromata have never been collected although the immature stage has been observed through the year.

Sphaeriales

Chaetomiaceae

Chaetomium cochliodes Palliser. Growing on cardboard and paper towel in damp chamber (Duncan, UBC 1904).

— **spirale** Zopf. On decaying plant remains of *Oxyria digyna* (Cathedral Lakes, UBC 1905).

Sordariaceae

Acanthorhynchus vaccinii Shear. On leaves of *Vaccinium oxycoccos* (Lulu Island, UBC 1926).

Bombardia ambigua (Sacc.) Wint. var. **carbonaria** Rehm. On wood covered with sand (University, UBC 1923).

Hypocopra gigaspora (Ell. & Ev.) Griffiths. On cow dung, described by Ellis and Everhart (14) as *Coprolepa gigaspora* (Rocky Mountains, June, 1897, Macoun, No. 684).

Sordaria fimicola (Rob.) Ces. & de Not. From seeds of *Cucurbita maxima* (Grand Forks, DAOM 14958, det. J. W. Groves); from seeds of *Daucus carota* (Okanagan Mission, DAOM 14282); on horse dung in damp chamber (University, UBC 1924).

— **hypocoproides** Speg. From seeds of *Raphanus sativus* (Grand Forks, DAOM 13539, det. R. F. Cain).

— **setosa** Winter. From seeds of *Beta vulgaris* (DAOM 15185, det. R. F. Cain).

Trichosphaeriaceae

Apiosporina collinsii (Schw.) Höhn. On *Amelanchier* spp. (Cariboo and Okanagan, UBC 606, 659, 671, 358, 1930, 1513, 1528, DAOM 7822, 25180).

Coleroa chaetomium (Kunze) Rab. On leaves of *Rubus parviflorus* (University, UBC 1922). This collection differs from var. *americana* Petrak by the stiff bristles of the perithecia.

— **oxyriae** Rostr. On dead leaves of *Oxyria digyna* (Cathedral Lakes, UBC 1905).

Coniochaeta leucoplaca (Berk. & Rav.) Cain. On cardboard in damp chamber (Duncan, UBC 1931); horse dung (University, UBC 1925).

Herpotrichia nigra Hartig. Eleven collections from all parts of the province on *Abies* spp., *Picea sitchensis*, *Tsuga heterophylla*.

Trichosphaeria breviseta Dear. On rotten coniferous wood, (Victoria, April, 1915, John Macoun), described by J. Dearness (9). A collection on bark of *Betula papyrifera* (Silver Creek, UBC 2331) appears to be this species.

MELANOMMEAE

Bertia moriformis (Tode) de Not. On bark of *Alnus* sp. (Vancouver Island, DAOM Feb. 10, 1915).

Melanomma cinereum (Karst.) Sacc. On *Salix babylonica* (North Vancouver, UBC 1927).

— **medium** Sacc. & Speg. On *Acer* sp. (University, UBC 1929).

— **parasiticum** Ell. & Ev. On stromata of *Diatrype* sp., on rotten wood (Comox, DAOM May 3, 1887).

— **pulvis-pyrius** (Pers.) Fckl. Common on dead wood; *Alnus oregona* (Cowichan Lake, det. R. Horner, DAOM 26114, UBC 1919); *Corylus californica* (Goldstream, DAOM 26094, UBC 1920); *Vaccinium corymbosum* (Lulu Island, det. R. Horner, DAOM 26185, UBC 1917); dead wood (UBC 1906, 1918, 1916).

— **sanguinarium** (Karst.) Sacc. On dead wood (Comox, DAOM 34). This specimen is presumably cotype material of *Lophiostoma aequivocum* Ell. (11), which Berlese considers a synonym of *Melanomma sanguinarium*. Berlese's drawings show the same characteristics as this collection, whose perithecia only rarely have compressed, slitlike ostioles (1).

Rosellinia obliquata (Somm.) Sacc. var. **americana** Ell. & Ev. On scales of dead cones of *Pinus ponderosa* (Vernon, UBC 1907).

— **ovalis** (Ell.) Sacc. On dead branches of *Artemisia tridentata* (Princeton, UBC 1909).

— **thelena** (Fr.) Rav. var. **pinea** Sacc. Ellis and Everhart (13) report this variety as sent from British Columbia by Dr. Macoun.

LOPHIOSTOMATACEAE

Lophiostoma caulium (Fr.) Ces. & de Not. On *Artemisia tridentata* (Princeton, UBC 1909); *Phlox speciosa* (Penticton, UBC 1902).

AMPHISPHAERIACEAE

Strickeria amelanchieris Earle. On weathered wood of *Amelanchier* sp. (Penticton, UBC 1928). Asci in this collection are considerably broader, up to 36 μ wide, otherwise as in the description.

— **obducens** (Fr.) Wint. On *Acer* sp. (University, UBC 1929); *Alnus* spp. (University, UBC 1910, Clearwater, UBC 666); *Artemisia tridentata* (Princeton, UBC 1909).

CERATOSTOMATACEAE

Ceratostomella sp. probably **C. sphaerosperma** (Fckl.) Sacc. On *Pinus monticola* (Silverton, UBC 1915).

CORYNELIACEAE

Caliciopsis pseudotsugae Fitzp. On *Pseudotsuga taxifolia*, (Daisy Lake, type, Fitzpatrick (16); Lake Cowichan, UBC 119, Nakusp, UBC 22, Sayward, UBC 1830, DAOM 21367).

MYCOSPHAERELLACEAE

Ascospora graminis Lind. On *Poa* sp. (Ootsa Lake, UBC 2005, 2006).

— **ruborum** (Oud.) Zeller. On *Rubus* sp. (CPDS 1939).

Guignardia bidwellii (Ell.) Viala & Ravaz. On *Vitis* sp. (CPDS 1933, 1946).

— **potentillae** (Rostr.) Lindau. On leaves of *Potentilla diversifolia* (Kennco Mining Camp, UBC 2003).

— **vaccinii** Shear. On *Arctostaphylos columbiana* (Duncan, UBC 2000).

Laestadia rhytismoides (Berk.) Sacc. On leaves of *Dryas* probably *D. drummondii* (Field, Saccardo (24)).

Mycosphaerella. Certain of these species are given as *Sphaerella*, without making new combinations at this time, since it is hoped to study type specimens in an effort to determine species limits in this genus.

— **arbuticola** (Pk.) House. On leaves of *Arbutus menziesii* (Saanich, UBC 771, 2101, CPDS 1931, 1934, 1937).

— **auerswaldii** (Fleisch.) Migula. On leaves of *Cornus nuttallii* (Duncan, UBC 2286). This collection has broader asci and spores than in the description (asci 45-75 × 10-23 μ, spores 22-30 × 4-7.5 μ).

— **brassicicola** (Duby) Lindau. On *Brassica oleracea* (Saanichton, UBC 772, 774, 775, Dewdney, UBC 773, CPDS 1943, 1945).

— **caricicola** (Fckl.) Lindau. On *Carex pyrenaica* (Penticton, UBC 2056); *Juncus drummondii* (Penticton, UBC 1989).

— **chimaphilae** (Ell. & Ev.) Höhn. On living leaves of *Chimaphila umbellata* (Armstrong, UBC 2127).

— **cinerascens** (Fckl.) Migula. On leaves of *Prunus emarginata* (University, UBC 2287).

— **coerulea** (Ell. & Ev.) Tracy & Earle. On *Aquilegia* spp. (Chilko River, UBC 2263, Tenquille Lake, UBC 2261, Revelstoke, UBC 2262).

— **confinis** (Karst.) Lind. On *Draba alpina* (Moose Mt., Pelly Creek, UBC 2138).

— **dolichospora** (Sacc. & Fautre) Wehm. On *Arenaria obtusiloba* (Cathedral Lakes, UBC 2067).

Sphaerella earliana Wint. On *Fragaria chiloensis* (Jordan River, UBC 2126).

Mycosphaerella eriophila (Niessl) Dear. On *Artemisia longepedunculata* (Chua Chua, UBC 2306); *Erigeron* sp. (Cathedral Lakes, UBC 2274, 2270).

— **fragariae** (Tul.) Lindau. On *Fragaria chiloensis* (CPDS 1926, 1933, 1934, 1937, 1939, 1940), as the imperfect stage *Ramularia tulasnei* Sacc.; on leaves of *Potentilla palustris* (Vancouver, UBC 1974).

— **graminicola** (Fckl.) Schroet. On *Distichlis spicata* (Lac la Hache, UBC 2187, Cariboo, UBC 2186).

— **grossulariae** (Fr.) Lindau. On *Ribes* sp. (CPDS 1926).

— **indistincta** (Pk.) Lindau. On *Pteridium aquilinum* (Saanichton, UBC 2096, Mount Seymour, UBC 2094). Spores are up to 38 μ long, otherwise as in the description.

— **innumerella** (Karst.) Schroet. On *Sibbaldia procumbens* (Cathedral Lakes, UBC 2144).

— **lineolata** (Rob. & Desm.) Schroet. On leaves of *Carex limosa* (Tetana River, UBC 2204).

Sphaerella microspila (B. & Br.) Cke. On *Epilobium angustifolium* (University, UBC 2093).

Mycosphaerella minor (Karst.) Johans. On stems and leaves of *Epilobium angustifolium* (Vernon, UBC 2164).

— **orbicularis** (Pk.) House. On leaves of *Populus tremuloides* (Saanichton, UBC 2012).

— **pachystimae** Dear. On living leaves of *Pachystima myrsinites* (Hope, UBC 2115). This collection has smaller asci (30-37 × 9-12 μ) and spores (10-12 × 3-4 μ) than in the description.

— **perexigua** (Karst.) Johans. On leaves of *Carex diandra* (Vanderhoof, UBC 2089).

— **pinodes** (B. & Blox.) Stone. On *Pisum sativum* (CPDS 1925).

— **polygonorum** (Crie) Lind. On *Eriogonum heracleoides* (Ashnola Trail, UBC 2143).

— **populifolia** (Cke.) House. On leaves of *Populus deltoides* (UBC 2142, det. J. E. Bier); *P. trichocarpa* (Vernon, UBC 2283).

— **punctiformis** (Pers.) Schroet. On leaves of *Acer macrophyllum* (University, UBC 1958, 1954, Silver Creek, UBC 1946); *Alnus oregona* (University, UBC 1959).

— **punctiformis** (Pers.) Schroet. var. **clematidis** Jaap. On *Arabis hirsuta* (Crawford Bay, UBC 2320); *Arenaria capillaris* (Fish Lake, UBC 2302); *Cirsium lanceolatum* (Vancouver Island, UBC 1969, 2316, DAOM 926); *Erigeron* sp. (Saanichton, UBC 2315); *Heuchera glabra* (Smithers, UBC 1880); *Senecio pauperculus* (Golden, UBC 2299).

— **pusilla** (Awd.) Johans. On *Carex flava* (Shawnigan Lake, UBC 2308).

— **ranunculi** (Karst.) Lind. On *Ranunculus eschscholtzii* (Garibaldi, UBC 2293).

— **rosicola** (Pass.) Davis. On *Rosa centifolia* var. *muscosa* (Patricia Bay, CPDS 1942).

— **rubi** Roark. On *Rubus* spp. (CPDS 1931-34, 1937, 1940, 1948). The conidial stage, *Septoria rubi* West., is of common occurrence.

— **sagedioides** (Wint.) Lindau. On *Cicuta douglasii* (Saanichton, UBC 2318).

— **stromatoidea** Dear. On living leaves of *Rumex* spp. (Fraser Valley and Vancouver Island, UBC 2108, 2147, 2103, 2102, 2100). Most of the collections noted here show asci, up to 70 μ long, and spores, 12-20 $\times$ 5-9 μ, somewhat larger than in the description.

— **tassiana** (de Not.) Johans. Following the usage of Lind (18) and Wehmeyer (31) this name is used to include all collections showing the typical broadly saccate asci which are constricted into a narrow tip with a much thickened wall, ranging in size from 27 to 97 $\times$ 12-30 μ, and spores 14-30 $\times$ 3.5-9 μ. This species is widespread throughout the province, found on leaves and stems of 192 collections of the following hosts: *Achillea* spp., *Agoseris gracilens*, *Agropyron* spp., *Agrostis* spp., *Allium* spp., *Anaphalis margaritacea*, *Andropogon scoparius*, *Anemone* spp., *Antennaria* spp., *Aplopappus brandegei*, *Aquilegia* spp., *Arabis* spp., *Arctagrostis latifolia*, *Arenaria* spp., *Arnica latifolia*, *Artemisia vulgaris*, *Aster conspicuus*, *Astragalus* spp., *Balsamorrhiza* sp., *Brassica* sp., *Bromus porteri*, *Calamagrostis* spp., *Campanula* sp., *Carex* spp., *Castilleja* spp., *Centaurea jacea*, *Cheiranthus* sp., *Chrysanthemum* sp., *Cichorium intybus*, *Cirsium* spp., *Crepis atribarba*, *Cucurbita maxima*, *Danthonia californica*, *Delphinium* sp., *Deschampsia* spp., *Draba* spp., *Elymus innovatus*, *Erigeron* spp., *Festuca* spp., *Gaillardia aristate*, *Geranium erianthum*, *Hieracium* spp., *Hierochloe* spp., *Hydrangea* sp., *Iris germanica*, *Juncus drummondii*, *Koeleria cristata*, *Lathyrus odoratus*, *Linum lewisii*, *Lomatium ambiguum*, *Lupinus* spp., *Luzula* spp., *Lychnis coronaria*, *Lycopersicum esculentum*, *Monarda mollis*, *Oenothera biennis*, *Oryzopsis* spp., *Panicum occidentale*, *Pedicularis* spp., *Penstemon ovatus*, *Phacelia leucophylla*, *Phleum alpinum*, *Phlox* spp., *Poa* spp., *Polemonium* spp., *Potentilla* spp., *Puccinellia nuttallina*, *Rumex acetosella*, *Sanicula crassicaulis*, *Schizachne purpurescens*, *Sedum stenopetalum*, *Senecio integerrimus*, *Silene douglasii*, *Sisyrinchium angustifolium*, *Sitanion hystrix*, *Solidago multiradiata*, *Sphenopholis obtusata*, *Spiraea lucida*, *Stellaria longipes*, *Stenanthium occidentale*, *Stipa* spp., *Symphoricarpos albus*, *Tanecetum vulgare*, *Tofieldia glutinosa*, *Trisetum spicatum*, *Zea mays*, *Zygadenus elegans*.

— **typhae** (Lasch.) Lindau. On *Typha latifolia* (Vancouver, UBC 2062).

Sphaerella vagans Ell. & Ev. On leaves of *Valeriana sitchensis* (Cathedral Lakes, UBC 2275).

Mycosphaerella wichuriana (Schroet.) Johans. On *Carex* spp. (Cariboo, UBC 2307, 2298, 2166); *Festuca idahoensis* (Elko, UBC 2297); *Luzula wahlenbergii* (McBride, UBC 2123); *Oryzopsis pungens* (Francois Lake, UBC 2227); *Poa* sp. (Francois Lake, UBC 2080, 2035).

Phaeosphaerella maculosa (Sacc.) Karst. On leaves of *Populus tremuloides* (Saanichton, UBC 2012).

Pleosphaerulina intermixta (Berk. & Br.) Berl. On stems of *Rosa* sp. (Sidney, DAOM April, 1915); petioles of *Alnus oregona* (Vancouver, UBC 1953). The collection on *Alnus* differs in the elongated ostiole and in the ellipsoid asci with a refractive ring at the apex.

Pseudoplea trifolii (Rostr.) Petrak. On leaves of *Medicago sativa* (University, UBC 2025).

Rehmiellopsis abietis (E. Rostr.) O. Rostr. On living leaves of *Abies lasiocarpa*, British Columbia (Waterman (28); CPDS 1945).

Sphaerulina gentianae Wehm. On *Gentiana calycosa* (Wall Lake, UBC 1933).

PLEOSPORACEAE

Apiosporella alpina Wehm. On *Pedicularis bracteosa* (Cathedral Lakes, UBC 2036). Wehmeyer (31) in his description states that no paraphyses nor paraphysis-like structures were present; in this collection they are distinct.

Caproniella pleiospora (Mout.) Berl. On bark of *Prunus demissa* (Vancouver, UBC 1956) Berlese (1) describes this species as having four- to five-septate spores with one or more of the middle cells longitudinally septate, but figures the spores three- to four- to five-septate. The original description does not mention spore septation. This collection is therefore placed in that species, although the asci are shorter and broader (45-60 $\times$ 18-21 μ) than in the description.

Clathrospora baccata Ell. On *Cirsium* spp. (Princeton, UBC 2111, 2110; Vancouver Island, DAOM 926).

— **diplospora** Ell. & Ev. On *Phlox longifolia* (Penticton, UBC 2112).

— **elynae** (Rab.) Ces. & de Not. On *Carex atratiformis* (Garibaldi, UBC 2054); *Luzula spicata* (Chua Chua, UBC 2124).

— **macrospora** Schroet. On *Arctagrostis latifolia* (Telegraph Creek District, UBC 2021); *Elymus innovatus* (Kechika River, UBC 2039).

— **pentamera** Karst. Eleven collections from all parts of the province on the following hosts: *Agropyron latiglume, Agrostis rossae, Andropogon scoparius, Calamagrostis purpurascens, Carex aperta, Oryzopsis hymenoides, Poa* spp., *Stipa comata.*

— **permunda** (Cke.) Sacc. On *Astragalus campestris* (Armstrong, UBC 2285); *Phlox* spp. (Penticton, UBC 2264, 2305); *Stipa comata* (Tranquille, UBC 2026).

— **planispora** Ell. On *Arabis* spp. (Okanagan, UBC 2320, 2321).

Didymella applanata (Niessl) Sacc. On stems of *Rubus* spp. (Fraser Valley and Vancouver Island, UBC 1973, 2022, CPDS 1931, 1932, 1934, 1936, 1937).

— **delphinii** Earle. On stems of *Arnica latifolia* (Cathedral Lakes, UBC 1972).

— **fenestrans** (Duby) Wint. On stalks of *Epilobium angustifolium* (University, UBC 1947, Mount Seymour, UBC 2018).

— **rauii** (Ell. & Ev.) Sacc. On stems of *Rosa* sp. (Sidney, DAOM April, 1915). Wehmeyer (30) says that this species should be placed in *Gnomonia* or *Gnomonina.*

— **trifolii** (Fckl.) Sacc. On stems of *Trifolium* sp. (Sidney, DAOM 370).

Didymellina macrospora Klebahn. On *Iris* sp. (CPDS 1930-37).

Didymosphaeria borgii Carnana-Gatto & Sacc. On stems of *Rosa* sp. (Saanichton, UBC 2024). This collection fits the description except for the occasional four-spored condition of the asci and for the constriction at the central septum of the spores.

— **oregonensis** Goodding. On *Alnus* spp. (Knight Inlet, UBC 324, Sayward, UBC 413, 665, Clearwater, UBC 666, det. D. C. Buckland).

Eriosphaeria herbarum Wehm. On stalks of *Pedicularis paddoensis* (Sage Pass, UBC 2335).

Leptosphaeria agnita (Desm.) Ces. & de Not. On *Erigeron speciosus* (Vernon, UBC 2064); *Lupinus latifolius* (Cathedral Lakes, UBC 2051).

— **andromedae** (Awd.) Sacc. On *Cassiope* sp. (Garibaldi, UBC 2050). This species is closely related to *Massaria.*

— **californica** (Cke. & Hark.) Sacc. On branches of *Cytisus* sp. (Duncan, UBC 2037). Doubtfully this species; the spores are often three- rather than four-septate.

— **camelliae** Cooke & Mass. On *Camellia* sp. (Saanichton, CPDS 1932).

— **coniothyrium** (Fckl.) Sacc. On *Rubus* spp. (CPDS 1928, 1931-40).

— **culmifraga** (Fr.) Ces. & de Not. Fourteen collections from all parts of the province on the following hosts: *Agropyron spicatum, Agrostis* spp., *Calamagrostis canadensis, Carex* spp., *Elymus macounii, Panicum occidentale, Poa* spp.

— **dumetorum** Niessl. On *Lonicera involucratum* (Harrison Lake, UBC 1971).

— **eustoma** (Fr.) Sacc. sensu Berl. On *Phleum alpinum* (Chilcoten, UBC 2049); *Typha latifolia* (Vancouver, UBC 2062).

— **fuckelii** Niessl. On *Phalaris arundinacea* (Ladner, UBC 2032).

— **gaultheriae** Dear. On dead stems of *Gaultheria shallon* (Vancouver Island, Macoun 980, Dearness (10)).

— **petkovicensis** Bub. & Ranoj. On *Carex* spp. (Vanderhoof, UBC 2089, Penticton, UBC 2056); *Juncus* spp. (Penticton, UBC 1989, Windermere, UBC 2034).

— **pratensis** Sacc. & Br. On *Melilotus* sp. (CPDS 1938).

— **silenes-acaulis** de Not. On *Silene acaulis* (Cathedral Lakes, UBC 2052).

— **tenera** Ell. On *Arabis drummondii* (Penticton, UBC 2055); *Draba stenoloba* (Penticton, UBC 2019).

— **typharum** (Desm.) Karst. sensu Berl. Twenty-two collections from all parts of the province on the following hosts: *Calamagrostis* spp., *Calamovilfa latifolia, Carex* spp., *Dactylis glomerata, Danthonia intermedia, Deschampsia atropurpurea, Elymus* spp., *Koeleria cristata, Panicum thermale, Poa* spp., *Trisetum spicatum.*

— **typhicola** Karst. On *Typha latifolia* (Vancouver, UBC 2062, immature).

— **vagans** Karst. sensu Berl. On *Carex atratiformis* (Garibaldi, UBC 2054). This species is similar to *L. typharum* but has broader asci and spores.

Metasphaeria macounii Dear. On dead decorticated stems of *Rosa* sp. (Vancouver Island, Macoun, June, 1915, Dearness (9)). A collection on *Rosa* sp. (Saanichton, UBC 2024) fits this description perfectly except that the spores become brown with end cells a lighter color.

— **culmifida** (Karst.) Sacc. f. **poae** (Niessl) Berl. On *Poa interior* (François Lake, UBC 2035).

— **zobeliana** Staritz. On *Delphinium brownii* (Vanderhoof, UBC 2033).

Ophiobolus acuminatus (Sow.) Duby. On stalks of *Cirsium lanceolatum* (Vancouver Island, DAOM 926, det. J. Dearness, UBC 1969).

— **cariceti** (Berk. & Br.) Sacc. (*O. graminis* Sacc.). On *Triticum aestivum* (Duncan, UBC 612, CPDS 1930, 1935, 1936, 1939, 1940); *Avena sativa* (CPDS 1939).

— **minor** Bubak. On dead twigs of *Lonicera involucratum* (Harrison Lake, UBC 1971).

— **porphyrogonus** (Tode) Sacc. On dead herbaceous stem (Duncan, UBC 1970).

— **rudis** (Riess.) Rehm. On stems of *Phacelia leptosepala* (Sage Pass, UBC 1968). Asci in this collection are longer (up to 210 μ) than in the description; spores separate at the septa into short cylindrical sections.

Phomatospora argyrostigma (Berk.) Sacc. On leaves of *Yucca* sp. (University, UBC 1952). This determination is doubtful, as no measurements of asci or spores were given in the description. Asci are 45-75 $\times$ 9-18 μ, spores 9-15 $\times$ 3-5 μ, with occasional large spores, 28-33 $\times$ 6-7.5 μ.

— **therophila** (Desm.) Sacc. On *Juncus drummondii* (Penticton, UBC 1989).

Physalospora miyabeana Fukushi. On *Salix* spp. (Fraser Valley, DAOM 6463, 6465, 6709, det. I. L. Conners, CPDS 1940).

— **obtusa** (Schw.) Cke. Recorded on apple (CPDS 1939, 1947, 1948, N. Saanich, Terrace, Pemberton Meadows). According to Stevens (27) this fungus is not found in the Pacific Northwest. No collections seen.

Pleospora ambigua (Berl. & Bres.) Wehm. var. **crandallii** (Ell. & Ev.) Wehm. On *Arenaria obtusiloba* (Cathedral Lakes, UBC 2067).

— **amplispora** Ell. & Ev. On *Draba stenoloba* (Penticton, UBC 2019).

— **angustata** Wehm. On *Artemisia vulgaris* (Cathedral Lakes, UBC 2152); *Gaillardia aristate* (Kootenay, UBC 2214).

— **armeriae** (Cda.) Ces. & de Not. Twelve collections from Vancouver and Vancouver Island on the following hosts: *Aquilegia formosa, Brassica* sp., *Campanula* sp., *Centaurea jacea, Lychnis coronaria, Oenothera* sp., *Pisum sativum, Primula* sp., *Sanicula crassicaulis.* These collections are separated from *P. herbarum* by the larger spores, 35-50 $\times$ 16-21 μ (Wehmeyer (37, 38)).

— **asymmestrica** Wehm. Eleven collections from alpine regions on the following hosts: *Achillea lanulosa, Antennaria media, Aplopappus brandegei, Artemisia longepedunculata, Astragalus glareosus, Erigeron* sp., *Lupinus latifolius, Ranunculus eschscholtzii, Viola adunca.*

— **balsamorrhizae** Tracy & Earle. On *Erigeron filifolius* (Osoyoos, UBC 2300); *Solidago decumbens* (Vanderhoof, UBC 2276).

— **coloradensis** Ell. & Ev. On *Anemone multifida* (Bennett, UBC 2129); *Astragalus campestris* (Armstrong, UBC 2285); *Phacelia leucophylla* (Vernon, UBC 1940).

— **comata** Niessl. Twenty-seven collections from all parts of the province on the following hosts: *Anemone* spp., *Aplopappus lyallii, Arabis canescens, Artemisia borealis, Castilleja miniata, Chrysopsis villosa, Erigeron* spp., *Oxytropis alpicola, Phacelia sericea, Phlox* spp., *Polemonium* spp., *Potentilla* spp., *Silene douglasii, Stenanthium occidentale.*

— **compositarum** Earle. On *Aquilegia formosa* (Pemberton, UBC 2261); *Draba paysonii* (Bella Coola, UBC 2265); *Erigeron* spp. (Kamloops, UBC 2211, 2064, Kootenay, UBC 2300, 2213); *Senecio pauperculus* (Golden, UBC 2299); *Stenanthium occidentale* (Field UBC 2323).

— **discors** (Mont.) Ces. & de Not. On *Carex hoodii* (Fort Fraser, UBC 2118); *Luzula campestris* (Mount Seymour, UBC 2106); *Poa* sp. (Kootenay, UBC 2080, Saanich, UBC 2228).

— **heleocharidis** Karst. On *Poa gracillima* (Garibaldi, UBC 2075); *Trisetum spicatum* (Garibaldi, UBC 2322).

— **helvetica** Niessl. On *Agropyron trachicaulum* (Fairmont, UBC 2140); *Anaphalis margaritacea* (Flagstone, UBC 2303); *Draba* spp. (Garibaldi, UBC 2294, Cathedral Lakes, UBC 2157); *Poa* spp. (Smithers, UBC 2231, Mount Rowe, UBC 2079).

— **herbarum** (Pers.) Rab. Twenty-one collections from Vancouver Island and Fraser Valley on the following hosts: *Allium cepa, Armeria maritima, Campanula* sp., *Cichorium intybus, Cirsium* sp., *Digitalis* sp., *Erigeron* sp., *Hieracium aurantiacum, Iris germanica, Lathyrus odoratus, Lupinus* sp., *Oenothera biennis, Pisum sativum, Rumex* sp., *Tanecetum vulgare, Trifolium* sp.

— **herbarum** (Pers.) Rab. var. **occidentalis** Wehm. On *Achillea millefolium* (Flagstone, UBC 2279); *Antennaria* spp. (Okanagan, UBC 2017, 1682, 2016); *Aster* sp. (Salmon Arm, UBC 2289); *Hieracium albertinum* (Flagstone, UBC 2199); *Penstemon tolmiei* (Penticton, UBC 2201); *Tofieldia coccinea* (Fort Nelson, UBC 2245).

— **media** Niessl var. **obtusa** Wehm. On *Campanula* sp. (Duncan, UBC 2099); Gramineae (Saanichton, UBC 2317).

— **njegusensis** Bub. On *Erigeron compositus* (Bennett, UBC 2210, 2209).

— **oligasca** Bub. Fifteen collections from alpine regions on the following hosts: *Antennaria* spp., *Dryas octopetala, Eriogonum* spp., *Geum triflorum, Potentilla* spp., *Senecio canus*. This species is distinctive in its small perithecia, often with a curved beaklike ostiole, its few, broad-saccate asci, and its spores which are at first hyaline and three- to four-septate, finally brown and four- to six-septate with the upper part short and globose and the lower part elongated, and with one or rarely two longitudinal septa in all but the end cells. Many of the collections listed here are immature, and are determined on the basis of perithecial size and shape and ascus shape.

— **tragacanthae** Rab. Seventeen collections from alpine regions on the following hosts: *Anemone drummondii, Antennaria microphylla, Arenaria* spp., *Draba praealta, Erigeron* spp., *Linum lewisii, Lupinus lyallii, Oxytropis cusickii, Pedicularis bracteosa, Phacelia sericea*.

— **trichostoma** (Fr.) Ces. & de Not. On *Hordeum vulgare* (CPDS 1935, as *Pyrenophora teres*).

— **vulgaris** Niessl var. **ferruginea** Wehm. On *Erigeron* sp. (Vernon, UBC 2288); *Iris germanica* (Duncan, UBC 1993); Liliaceae indet. (Duncan, UBC 2295).

— **vulgaris** Niessl var. **vulgaris**. On *Balsamorrhiza* sp. (Vernon, UBC 2162); *Phacelia leucophylla* (Vernon, UBC 1941); herbaceous stalks (Penticton, UBC 2281).

Protoventuria vancouverensis Dear. On bark of dead *Acer* sp. (Vancouver Island, J. Macoun, 1003, Dearness (10)).

Venturia atriseda Rehm. On stalks of *Gentiana calycosa* (Wall Lake, UBC 1933).

— **cassandrae** Pk. On *Ledum groenlandicum* (Burnaby Lake, UBC 2070). No species of *Venturia* has been reported on *Ledum*; this description most nearly fits the collection.

— **chlorospora** (Ces.) Karst. On leaves of *Salix* sp. (University, UBC 1967). The spores in this collection are small, 9-15 × 3-4 μ.

— **dickiei** (B. & Br.) de Not. On living leaves of *Linnaea borealis* var. *americana* (Canoe, UBC 1587).

— **inaequalis** (Cke.) Aderh. On *Pyrus malus*, common throughout the apple-growing regions of the province (CPDS 1926, 1928-40).

— **myrtilli** Cke. On *Cassiope stellariana* (Hope, UBC 1936).

— **pyrina** Aderh. Common on *Pyrus communis* throughout the province (UBC 1932, 471, CPDS 1926, 1930, 1931, 1935-40).

— **rumicis** (Desm.) Wint. On leaves of *Rumex acetosella* (Mount Seymour, UBC 1934, Bennett, UBC 1935).

GNOMONIACEAE

Glomerella cingulata (Ston.) Schrenk & Spauld. Reported on *Pyrus malus* (CPDS 1931).

Gnomonia depressula Karst. On dead stems of *Rubus parviflorus* (University, UBC 1973).

— **fragariae** Klebahn. On petioles of *Potentilla palustris* (Vancouver, UBC 1974). In this collection the asci are somewhat broader, 60-70 × 13-15 μ, and the spores larger, 21-24 × 6-7 μ, than in the description.

— **setacea** (Pers.) Ces. & de Not. On leaves of *Acer macrophyllum* (Silver Creek, UBC 1946, University, UBC 1954, 1958); *Alnus oregona* (Vancouver, 1953, 1959).

— **veneta** (Sacc. & Speg.) Klebahn. On leaves of *Platanus occidentalis* (Sidney, UBC 797, CPDS 1934).

— **vepris** Mout. On leaves of *Rubus parviflorus* (University, UBC 1922). Although not previously noted in North America, this collection fits the description well. Asci are very small, 27-30 × 7-9 μ, spores 9-12 × 1.5-2.5 μ.

Gnomoniella coryli (Batsch ex Fr.) Sacc. On *Corylus* spp. (Revelstoke, UBC 1949, DAOM 7519, det. I. L. Conners, Aleza Lake, UBC 1951, Vancouver, DAOM Aug. 17, 1916, det. H. T. Gussow, Hope, UBC 1950, det. D. B. O. Savile, Kersley, UBC 1669). Few of the collections show mature asci; in most the perithecia are filled with globose hyaline cells.

Clypeosphaeriaceae

Ceuthocarpon brunellae (Ell. & Ev.) Berl. On living leaves of *Prunella vulgaris* (Vancouver Island, UBC 436, 63, 613, DAOM 15328, 19994).

Linospora insularis Johans. On leaf of *Salix* sp. (University, UBC 1967). This collection has larger asci (250-300 × 7.5-10 μ) and septate spores (225 × 1.5 μ) than any species recorded, but most nearly fits *L. insularis* in size and in the lateral position of the curved beak.

Nitschkieae

Acanthonitschkea coloradensis Cash & Davidson. On bark of *Abies lasiocarpa* (Cathedral Lakes, UBC 1911).

Cucurbitariaceae

Cucurbitaria typhina Ell. & Ev. On *Rhus glabra* (University, UBC 1955). This collection differs from the species in the constriction at the central septum of the spores, whose end cells are subhyaline. According to Welch (39) this species belongs to *Strickeria* (*Teichospora*).

Massariaceae

Massaria macrotheca (Rostr.) Lind. On *Carex* sp. (Cathedral Lakes, UBC 1963). The spores finally become light brown.

Massarina dryadis Rostr. On *Dryas drummondii* (Field, UBC 1966). Only incomplete descriptions of spores were found; in this collection they are three-septate, hyaline, oblong, constricted, surrounded by a broad gelatinous envelope, 33-42 × 15-20 μ.

Allantosphaeriaceae

Cryptosphaeria populina (Pers.) Sacc. On *Populus* sp. (Summerland, DAOM 7862, det. I. L. Conners).

Diatrype bullata (Hoff.) Fr. On *Salix* (Saanichton, DAOM 14361, det. I. L. Conners).

— **disciformis** (Hoff.) Fr. On bark of *Alnus* sp. (Hastings, DAOM 35*b*).

— **macounii** Ell. & Ev. Described by Ellis and Everhart (12) on "(*Acer rubrum*)?; Agassiz, May, 1889. Macoun, No. 127." The cotype is labelled "on alder bark" (DAOM 127). On *Populus trichocarpa* (White Rock, UBC 1944); *Populus* sp. (Vancouver Island, DAOM Sept. 29, 1914, and April 8 and 18, 1915, det. J. Dearness).

— **stigma** (Hoff.) de Not. On *Betula fontinalis* (Salmon Arm, UBC 1941).

Diatrypella betulina Pk. On *Betula* spp. (Cariboo, UBC 1942, 1943).

— **tocciaeana** de Not. On bark of *Alnus* sp. (Sidney, DAOM 30, det. J. Dearness).

Eutypella stellulata (Fr.) Sacc. On bark of *Alnus* spp. (University, UBC 1829, Vancouver Island, DAOM 36, 1912, Sept. 13, 1913, det. J. Dearness); *Betula occidentalis* (Quesnel, UBC 2324); *Populus* sp. (Sidney, DAOM 38).

Diaporthaceae

Apioporthe vepris (De Lacr.) Wehm. On stems of *Rubus macropetalus* (Cowichan Bay, UBC 1960).

Cryptodiaporthe macounii (Dear.) Wehm. On *Spiraea menziesii* (Vancouver Island, May 1915, J. Macoun). This species was described by Dearness (9) as *Diaporthe macounii* and transferred to *Cryptodiaporthe* by Wehmeyer (30).

— **salicina** (Curr.) Wehm. On twigs of *Salix* sp. (Sidney, DAOM 243), determined as *Diaporthe salicella* by Dearness, but similar to N.A.F. 2745; on *Salix* sp. (Fraser Valley, DAOM 7184).

Diaporthe arctii (Lasch.) Nit. On stalks of *Arnica latifolia* (Cathedral Lakes, UBC 1972).

—**columbiensis** Ell. & Ev. Original host given as unknown (12);cotype (DAOM 32, Hastings) is labelled "on dead aspen". Reported by Dearness (9) on *Nuttallia cerasiformis* (Victoria); given as *Rosa* sp. in the New York Mus. Herb. (Wehmeyer (30)).

— **eres** Nit. On *Acer* sp. (Duncan, UBC 1957): *Populus trichocarpa* (Surrey, UBC 1858); *Salix babylonica* (North Vancouver, UBC 1927, det. L. E. Wehmeyer (37)). According to Dr. Wehmeyer, this fungus has not been previously reported in North America on *Salix*.

— **exiguestroma** Dear. Described (10) from dead stems of *Rosa* sp. (Vancouver Island, Macoun 923); according to Wehmeyer (30), this is a *Didymella*.

— **pardolata** (Mont.) Fckl. On *Epilobium angustifolium* (University, UBC 1947).

Endothia parasitica (Murr.) A. & A. On bark of *Castanea sativa* (Agassiz, DAOM 370, 2992, CPDS 1941). Only the conidial stage seen. Reported by Faull and Graham (15) in 1914 for the first time in British Columbia.

Fenestella princeps Tul. On bark of *Prunus demissa* (Vancouver, UBC 1956); on bark (Vancouver Island, DAOM 17, 68).

Melanconis alni Tul. On *Alnus sitchensis* (Daisy Lake, DAOM 767, det. J. Dearness).

— **thelebola** (Fr.) Sacc. On *Alnus oregona* (Cowichan Lake, DAOM 26101, University, UBC 1921). This species is common in the Fraser Valley and Vancouver Island, forming cankers on branches and trunks of young alders.

Valsa ambiens (Pers.) Fr. On bark of *Pyrus malus* (Sidney, DAOM 202, det. J. Dearness).

— **ceratophora** Tul. On *Betula* sp. (Hastings, DAOM 34*a*); *Rubus* sp. (Vancouver Island, DAOM 19, det. J. Dearness).

— **leucostoma** (Pers.) Fr. On *Pyrus malus* (Vancouver Island, DAOM 37, 73, det. J. Dearness); *Prunus persica* (Sandwick, UBC 466); nectarine (CPDS 1945).

— **nivea** (Hoff.) Fr. On *Populus* sp. (Cariboo, UBC 1948).

— **pini** (Alb. & Schw.) Fr. On *Pseudotsuga taxifolia* (Cowichan Lake, DAOM 6098, det. I. L. Conners).

— sp. Reported on peach (Vancouver Island, CPDS 1947).

Calosphaeriaceae

Calosphaeria princeps Tul. On *Amelanchier* sp. (Spences Bridge, UBC 1945).

Xylariaceae

Daldinia concentrica (Bolt.) Ces. & de Not. On logs (Slocan City, DAOM Aug. 21, 1900); *Betula fontinalis* (Summerland, UBC 1578, sterile). According to Child (6), *D. concentrica* is not found in western North America; however the specimens mentioned here do not show any bronze color in the stromata but are black, spores are slightly larger than in *D. occidentale*.

— **occidentale** Child. Mentioned by Child (6) from Bendigo, Victoria, June 1918, E. J. Summers (L-10806); on *Betula* spp. (Cheetzi, CPDS 1933).

Hypoxylon aspera Mass. On *Tsuga heterophylla* (Turnour Island, UBC 1908, det. J. H. Miller (22)). Dr. Miller considers this an unusual host for the species.

— **atropurpureum** Fr. Cited by Ellis and Everhart (13) on bark, Macoun. Macoun's collection on rotten wood (Comox, DAOM 28) has asci larger than in the description, 90-105 × 6-7 μ, and spores 9-13.5 × 4.5-6 μ. It is close to *H. multiforme*.

— **concurrens** B. & C. ? On dead wood, sterile (Hastings, DAOM 36). Dearness says of this collection: "Mr. Ellis mentions only two records of *H. concurrens* – Carolina and California. This was probably referred to him, in which case if he had thought it *H. concurrens* he would likely have recorded it."

— **crustaceum** Nit. Reported by Ellis and Everhart (13), on decorticated wood, British Columbia, Macoun.

— **fuscum** (Pers.) Fr. On *Alnus oregona* (Vancouver and Vancouver Island, UBC 1855, 1857, 1854, DAOM 167, 35, 60); *Betula* sp. (Hastings, DAOM 56). One collection on *Populus tremuloides* (Ashnola District, UBC 1860), fits this species, although Miller (20) says that *H. fuscum* is found only on *Alnus*, *Betula*, and *Corylus* spp.

— **multiforme** Fr. First recorded from British Columbia by Ellis and Everhart (13) on *Alnus* sp., Macoun. On *Alnus oregona* (University, UBC 127, Vancouver Island, UBC 1856); *Betula* sp. (Hastings, DAOM 23, Cinema, UBC 1852, Sicamous, DAOM 164); *Populus trichocarpa* (Surrey, UBC 1858); *Populus* sp. (Vancouver Island, DAOM 322, 15, 27, 51, 63).

— **perforatum** (Schw.) Sacc. On *Populus* sp. (Saanichton, DAOM March 24, 1915). Asci are longer (108-120 × 10-12 μ) than in the description.

— **pruinatum** (Klotsche) Cke. On *Populus tremuloides* (Green Lake, UBC 74, det. D. C. Buckland).

— **serpens** Pers. ex Fr. var. **macrosporum** Miller. On dead wood (Comox, DAOM 29).

— **ustulatum** (Bull.) Fr. Common around stumps, on *Acer macrophyllum* (Vancouver Island and Vancouver, UBC 1850, 1848, 1847, DAOM 1994, 6487, 23323); *Alnus ?* sp. (Goldstream, DAOM 4387); burned log (Goldstream, UBC 1849).

— **vogesiacum** Pers. ex Sacc. On *Alnus* sp. (Cowichan Lake, UBC 1851).

Xylaria hypoxylon (L.) Grev. On *Alnus oregona* (Cowichan Lake, UBC 307, Vancouver, UBC 1853, 129); rotten wood (University, UBC 1859, Sidney, DAOM 19, 20, 46, conidial stage only).

— sp. On rotten wood (Cedar Hill, DAOM 67). Dearness would place it under *X. arbuscula* or *X. apiculata*.

Dothideales

Dothideaceae

Cucurbidothis pithyophila (Fr.) Petrak. On *Pinus monticola* (Nakusp, UBC 1835, Vancouver Island, UBC 1833, 1834, DAOM 26771).

Cymadothea trifolii (Pers.) Wolf. On *Trifolium* spp.; only the conidial stage, *Polythrincium trifolii* Kze., causing a sooty blotch of the leaves, has been collected.

Dibotryon morbosum (Schw.) Theiss. & Syd. On *Prunus* spp., 15 collections from all parts of the province.

Endodothella tracyi (Ell. & Ev.) Theiss. & Syd. On *Distichlis stricta* (Oliver, DAOM 15234, det. I. L. Conners).

Phyllachora graminis (Pers.) Fckl. On *Dactylis glomerata* (Harrison Lake, UBC 1836); *Elymus condensatus* (University, UBC 1832); *Poa* sp. (Lulu Island, UBC 1831, Kamloops, DAOM 154).

— **silvatica** Sacc. & Speg. On *Festuca rubra* (Sidney, UBC 760).

Acknowledgments

This study was made possible by a bursary and two summer research grants from the National Research Council of Canada. The writer wishes to thank Dr. F. Dickson for suggestions and encouragement during the study, Dr. L. E. Wehmeyer for confirmation of certain identifications, and Dr. J. W. Groves for criticism of the manuscript.

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(NOTE: *Host Index on pp. 824–830.*)

Host Index

Abies spp.
Acanthonitschkia coloradensis
Creonectria cucurbitula
Dimerosporium abietis
Herpotrichia nigra
Rehmiellopsis abietis

Acer spp.
Creonectria coccinea
Creonectria mammoidea
Creonectria purpurea
Diaporthe eres
Gnomonia setacea
Hypoxylon ustulatum
Melanomma medium
Mycosphaerella punctiformis
Protoventuria vancouverensis
Strickeria obducens
Uncinula aceris
Uncinula circinatum

Achillea spp.
Mycosphaerella tassiana
Pleospora asymmetrica
Pleospora herbarum var. occidentalis

Agoseris spp.
Mycosphaerella tassiana
Sphaerotheca humuli var. fuliginea

Agropyron spp.
Clathrospora pentamera
Claviceps purpurea
Erysiphe graminis
Leptosphaeria culmifraga
Mycosphaerella tassiana
Pleospora helvetica

Agrostis spp.
Clathrospora pentamera
Leptosphaeria culmifraga
Mycosphaerella tassiana

Allium spp.
Mycosphaerella tassiana
Pleospora herbarum

Alnus spp.
Bertia moriformis
Creonectria pithoides
Creonectria purpurea
Diatrype disciformis
Diatrypella tocciaeana
Didymosphaeria oregonensis
Erysiphe aggregata
Eutypella stellulata
Gnomonia setacea
Hypoxylon fuscum
Hypoxylon multiforme
Hypoxylon ustulatum
Hypoxylon vogesiacum
Melanconis alni
Melanconis thelebola
Melanomma pulvis-pyrius
Mycosphaerella punctiformis
Phyllactinia corylea

Alnus spp.—*con.*
Pleosphaerulina intermixta
Strickeria obducens
Xylaria hypoxylon

Amaranthus sp.
Melanospora townei

Amelanchier spp.
Apiosporina collinsii
Calosphaeria princeps
Phyllactinia corylea
Strickeria amelanchieris

Anaphalis spp.
Mycosphaerella tassiana
Pleospora helvetica

Andropogon spp.
Clathrospora pentamera
Mycosphaerella tassiana

Anemone spp.
Mycosphaerella tassiana
Pleospora coloradensis
Pleospora comata
Pleospora tragacanthae

Antennaria spp.
Mycosphaerella tassiana
Pleospora asymmetrica
Pleospora herbarum var. occidentalis
Pleospora oligasca
Pleospora tragacanthae

Antirrhinum sp.
Erysiphe sp.

Aplopappus spp.
Mycosphaerella tassiana
Pleospora asymmetrica
Pleospora comata

Aquilegia spp.
Erysiphe polygoni
Mycosphaerella coerulea
Mycosphaerella tassiana
Pleospora armeriae
Pleospora compositarum

Arabis spp.
Clathrospora planispora
Leptosphaeria tenera
Mycosphaerella punctiformis var. clematidis
Mycosphaerella tassiana
Pleospora comata

Arbutus sp.
Mycosphaerella arbuticola

Arctagrostis spp.
Clathrospora macrospora
Mycosphaerella tassiana

Arctostaphylos sp.
Guignardia vaccinii

Host Index—*Continued*

Arenaria spp.
- Mycosphaerella dolichospora
- Mycosphaerella punctiformis var. clematidis
- Mycosphaerella tassiana
- Pleospora ambigua var. crandallii
- Pleospora tragacanthae

Armeria sp.
- Pleospora herbarum

Arnica spp.
- Diaporthe arctii
- Didymella delphinii
- Mycosphaerella tassiana
- Nectriella sp.

Artemisia spp.
- Erysiphe sp.
- Lophiostoma caulium
- Mycosphaerella eriophila
- Mycosphaerella tassiana
- Pleospora angustata
- Pleospora asymmetrica
- Pleospora comata
- Rosellinia ovalis
- Strickeria obducens

Aster spp.
- Erysiphe cichoracearum
- Mycosphaerella tassiana
- Pleospora herbarum var. occidentalis

Astragalus spp.
- Asterella hellebori
- Clathrospora permunda
- Mycosphaerella tassiana
- Pleospora asymmetrica
- Pleospora coloradensis

Avena spp.
- Claviceps purpurea
- Erysiphe graminis
- Ophiobolus cariceti

Balsamorrhiza spp.
- Mycosphaerella tassiana
- Pleospora vulgaris var. vulgaris

Beta sp.
- Petriella asymmetrica
- Sordaria setosa

Betula spp.
- Daldinia concentrica
- Daldinia occidentale
- Diatrype stigma
- Diatrypella betulina
- Eutypella stellulata
- Hypoxylon fuscum
- Nectria sanguinea
- Trichosphaeria breviseta
- Valsa ceratophora

Bidens sp.
- Sphaerotheca humuli var. fuliginea

Brassica spp.
- Erysiphe polygoni
- Mycosphaerella brassicicola
- Mycosphaerella tassiana
- Pleospora armeriae

Bromus spp.
- Claviceps purpurea
- Mycosphaerella tassiana

Calamagrostis spp.
- Clathrospora pentamera
- Claviceps purpurea
- Leptosphaeria culmifraga
- Leptosphaeria typharum
- Mycosphaerella tassiana

Calamovilfa sp.
- Leptosphaeria typharum

Callistephus sp.
- Erysiphe cichoracearum

Camellia sp.
- Leptosphaeria camelliae

Campanula spp.
- Mycosphaerella tassiana
- Pleospora herbarum
- Pleospora media var. obtusa

Carex spp.
- Clathrospora elynae
- Clathrospora pentamera
- Claviceps grohii
- Leptosphaeria culmifraga
- Leptosphaeria petkovicensis
- Leptosphaeria typharum
- Leptosphaeria vagans
- Massaria macrotheca
- Mycosphaerella caricicola
- Mycosphaerella lineolata
- Mycosphaerella perexigua
- Mycosphaerella pusilla
- Mycosphaerella tassiana
- Mycosphaerella wichuriana
- Pleospora discors

Cassiope spp.
- Leptosphaeria andromedae
- Venturia myrtilli

Castanea sp.
- Endothia parasitica

Castilleja spp.
- Mycosphaerella tassiana
- Pleospora comata
- Sphaerotheca humuli var. fuliginea

Centaurea sp.
- Mycosphaerella tassiana
- Pleospora armeriae

Chaenomeles sp.
- Creonectria purpurea

Cheiranthus sp.
- Mycosphaerella tassiana

Host Index—*Continued*

Chimaphila sp.
Mycosphaerella chimaphilae

Chiogenes sp.
Microsphaera alni var. vaccinii

Choisya sp.
Creonectria purpurea

Chrysanthemum sp.
Erysiphe cichoracearum
Mycosphaerella tassiana

Chrysopsis sp.
Pleospora comata

Cichorium sp.
Mycosphaerella tassiana
Pleospora herbarum

Cicuta sp.
Mycosphaerella sagedioides

Cirsium spp.
Clathrospora baccata
Mycosphaerella punctiformis var. clematidis
Mycosphaerella tassiana
Pleospora herbarum

Comandra sp.
Erysiphe polygoni

Coreopsis sp.
Sphaerotheca humuli var. fuliginea

Cornus sp.
Mycosphaerella auerswaldii
Phyllactinia corylea

Corylus spp.
Gnomoniella coryli
Melanomma pulvis-pyrius
Phyllactinia corylea

Crataegus sp.
Phyllactinia corylea

Crepis sp.
Mycosphaerella tassiana

Cucumis spp.
Erysiphe cichoracearum
Petriella asymmetrica

Cucurbita spp.
Mycosphaerella tassiana
Sordaria fimicola

Cytisus sp.
Leptosphaeria californica

Dactylis spp.
Erysiphe graminis
Leptosphaeria typharum
Phyllachora graminis

Danthonia sp.
Leptosphaeria typharum
Mycosphaerella tassiana

Daucus sp.
Sordaria fimicola

Delphinium spp.
Erysiphe cichoracearum
Erysiphe polygoni
Metasphaeria zobeliana
Mycosphaerella tassiana

Deschampsia sp.
Leptosphaeria typharum
Mycosphaerella tassiana

Diaporthe sp.
Nectria episphaeria

Diatrype spp.
Melanomma parasiticum
Nectria episphaeria

Digitalis sp.
Pleospora herbarum

Distichlis spp.
Endodothella tracyi
Mycosphaerella graminicola

Draba spp.
Acrospermum compressum
Leptosphaeria tenera
Mycosphaerella confinis
Mycosphaerella tassiana
Pleospora amplispora
Pleospora compositarum
Pleospora helvetica
Pleospora tragacanthae

Dryas spp.
Laestadia rhytismoides
Massarina dryadis
Pleospora oligasca

Elymus spp.
Clathrospora macrospora
Claviceps purpurea
Leptosphaeria culmifraga
Leptosphaeria typharum
Mycosphaerella tassiana
Phyllachora graminis

Epilobium spp.
Diaporthe pardolata
Didymella fenestrans
Mycosphaerella minor
Sphaerella microspila

Erigeron spp.
Leptosphaeria agnita
Mycosphaerella eriophila
Mycosphaerella tassiana
Pleospora asymmetrica
Pleospora balsamorrhizae
Pleospora comata
Pleospora compositarum
Pleospora herbarum
Pleospora njegusensis
Pleospora tragacanthae
Pleospora vulgaris var. ferruginea

Host Index—*Continued*

Eriogonum spp.
- Mycosphaerella polygonorum
- Mycosphaerella punctiformis var. clematidis
- Pleospora oligasca

Eutypella sp.
- Nectria episphaeria

Festuca spp.
- Claviceps purpurea
- Mycosphaerella tassiana
- Mycosphaerella wichuriana
- Phyllachora silvatica

Ficus sp.
- Creonectria purpurea

Fomes spp.
- Hypomyces aurantius

Fragaria spp.
- Mycosphaerella fragariae
- Sphaerella earliana
- Sphaerotheca humuli

Gaillardia sp.
- Mycosphaerella tassiana
- Pleospora angustata

Gaultheria sp.
- Asterella gaultheriae
- Leptosphaeria gaultheriae

Gentiana sp.
- Sphaerulina gentianae
- Venturia atriseda

Geranium spp.
- Mycosphaerella tassiana
- Sphaerotheca humuli
- Stigmatea robertiani

Geum sp.
- Pleospora oligasca

Gilia sp.
- Sphaerotheca humuli

Heuchera spp.
- Mycosphaerella punctiformis var. clematidis
- Sphaerotheca humuli

Hieracium spp.
- Mycosphaerella tassiana
- Pleospora herbarum
- Pleospora herbarum var. occidentalis

Hierochloe sp.
- Mycosphaerella tassiana

Holcus sp.
- Epichloe typhina

Holodiscus sp.
- Phyllactinia corylea

Hordeum spp.
- Claviceps purpurea
- Erysiphe graminis
- Pleospora trichostoma

Hydrangea sp.
- Mycosphaerella tassiana

Hypoxylon sp.
- Nectria episphaeria

Iris spp.
- Didymellina macrospora
- Mycosphaerella tassiana
- Pleospora herbarum
- Pleospora vulgaris var. ferruginea

Juncus spp.
- Leptosphaeria petkovicensis
- Mycosphaerella caricicola
- Mycosphaerella tassiana
- Phomatospora therophila

Juniperus spp.
- Stigmatea sequoiae

Koeleria sp.
- Leptosphaeria typharum
- Mycosphaerella tassiana

Lactarius sp.
- Hypomyces lactifluorum

Lactuca spp.
- Erysiphe cichoracearum
- Sphaerotheca humuli var. fuliginea

Lathyrus spp.
- Erostrotheca multiformis
- Erysiphe polygoni
- Mycosphaerella tassiana
- Pleopora herbarum

Ledum sp.
- Venturia cassandrae

Linnaea sp.
- Venturia dickiei

Linum sp.
- Mycosphaerella tassiana
- Pleospora tragacanthae

Lolium sp.
- Claviceps purpurea

Lomatium sp.
- Mycosphaerella tassiana

Lonicera spp.
- Leptosphaeria dumetorum
- Microsphaera alni var. lonicerae
- Ophiobolus minor

Lotus sp.
- Erysiphe polygoni

Lupinus spp.
- Erysiphe polygoni
- Leptosphaeria agnita
- Mycosphaerella tassiana
- Nectriella sp.
- Pleospora asymmetrica
- Pleospora herbarum
- Pleospora tragacanthae

Host Index—*Continued*

Luzula spp.
Clathrospora elynae
Mycosphaerella tassiana
Mycosphaerella wichuriana
Pleospora discors

Lychnis sp.
Mycosphaerella tassiana
Pleospora armeriae

Lycopersicum sp.
Mycosphaerella tassiana

Matthiola sp.
Erysiphe polygoni

Medicago spp.
Pseudoplea trifolii

Melanconis sp.
Nectria episphaeria

Melilotus sp.
Leptosphaeria pratensis

Monarda sp.
Mycosphaerella tassiana

Myrica sp.
Uncinula salicis

Nuttallia sp.
Diaporthe columbiensis

Oenothera sp.
Erysiphe cichoracearum
Mycosphaerella tassiana
Pleospora armeriae
Pleospora herbarum

Oryzopsis spp.
Clathrospora pentamera
Mycosphaerella tassiana
Mycosphaerella wichuriana

Oxyria sp.
Chaetomium spirale
Coleroa oxyriae

Oxytropis sp.
Pleospora comata
Pleospora tragacanthae

Pachystima sp.
Mycosphaerella pachystimae

Panicum spp.
Leptosphaeria culmifraga
Leptosphaeria typharum
Mycosphaerella tassiana

Parthenocissus sp.
Uncinula necator

Pedicularis spp.
Apiosporella alpina
Eriosphaeria herbarum
Mycosphaerella tassiana
Pleospora tragacanthae

Penstemon spp.
Dimerium alpinum
Erysiphe cichoracearum
Mycosphaerella tassiana
Pleospora herbarum var. occidentalis

Phacelia spp.
Mycosphaerella tassiana
Ophiobolus rudis
Pleospora coloradensis
Pleospora comata
Pleospora tragacanthae
Pleospora vulgaris var. vulgaris

Phalaris sp.
Leptosphaeria fuckelii

Phaseolus sp.
Melanospora papillata

Phleum spp.
Claviceps purpurea
Leptosphaeria eustoma
Mycosphaerella tassiana

Phlox spp.
Clathrospora diplospora
Clathrospora permunda
Erysiphe cichoracearum
Lophiostoma caulium
Mycosphaerella tassiana
Nectriella sp.
Pleospora comata

Picea sp.
Herpotrichia nigra

Pinus spp.
Ceratostomella sp.
Cucurbidothis pithyophila
Rosellinia obliquata var. americana

Pisum sp.
Erysiphe polygoni
Mycosphaerella pinodes
Pleospora armeriae
Pleospora herbarum

Plantago sp.
Erysiphe cichoracearum

Platanus sp.
Gnomonia veneta

Poa spp.
Ascospora graminis
Clathrospora pentamera
Erysiphe graminis
Leptoshpaeria culmifraga
Leptosphaeria typharum
Metasphaeria culmifida
Mycosphaerella tassiana
Mycosphaerella wichuriana
Phyllachora graminis
Pleospora discors
Pleospora heleocharidis
Pleospora helvetica

Host Index—*Continued*

Polemonium spp.
Mycosphaerella tassiana
Pleospora comata

Polygonum spp.
Erysiphe polygoni

Polyporus sp.
Hypomyces aurantius

Populus spp.
Cryptosphaeria populina
Diaporthe eres
Diatrype macounii
Eutypella stellulata
Hypoxylon fuscum
Hypoxylon multiforme
Hypoxylon perforatum
Hypoxylon pruinatum
Mycosphaerella orbicularis
Mycosphaerella populifolia
Phaeosphaerella maculosa
Uncinula salicis
Valsa nivea

Potentilla spp.
Gnomonia fragariae
Guignardia potentillae
Microthyrium arcticum
Mycosphaerella fragariae
Mycosphaerella tassiana
Pleospora comata
Pleospora oligasca
Sphaerotheca humuli

Primula sp.
Pleospora armeriae

Prunella sp.
Ceuthocarpon brunellae

Prunus spp.
Caproniella pleiospora
Dibotryon morbosum
Fenestella princeps
Mycosphaerella cinerascens
Podosphaera oxyacanthae
Sphaerotheca pannosa

Pseudotsuga sp.
Caliciopsis pseudotsugae
Phaeocryptopus gaumannii
Valsa pini

Pteridium sp.
Mycosphaerella indistincta

Puccinellia sp.
Mycosphaerella tassiana

Pyrus spp.
Creonectria purpurea
Glomerella cingulata
Nectria galligena
Podosphaera leucotricha
Valsa ambiens
Valsa leucostoma
Venturia inaequalis
Venturia pyrina

Quercus sp.
Microsphaera alni

Ranunculus sp.
Mycosphaerella ranunculi
Pleospora asymmetrica

Raphanus sp.
Petriella asymmetrica
Sordaria hypocoproides

Rhus spp.
Cucurbitaria typhina
Erysiphe sp.
Sphaerotheca humuli

Ribes spp.
Mycosphaerella grossulariae
Sphaerotheca mors-uvae

Rosa spp.
Diaporthe exiguestroma
Didymella rauii
Didymosphaeria borgii
Metasphaeria macounii
Mycosphaerella rosicola
Pleosphaerulina intermixta

Rubus spp.
Apioporthe vepris
Ascospora ruborum
Asterina rubicola
Coleroa chaetomium
Creonectria purpurea
Didymella applanata
Gnomonia depressula
Gnomonia vepris

Leptosphaeria coniothyrium
Mycosphaerella rubi
Sphaerotheca humuli
Sphaerotheca humuli var. fuliginea
Valsa ceratophora

Rudbeckia sp.
Erysiphe cichoracearum

Rumex spp.
Mycosphaerella stromatoidea
Mycosphaerella tassiana
Pleospora herbarum
Venturia rumicis

Salix spp.
Cryptodiaporthe salicina
Diaporthe eres
Diatrype bullata
Linospora insularis
Melanomma cinereum
Physalospora miyabeana
Uncinula salicis
Venturia chlorospora

Sanicula sp.
Mycosphaerella tassiana
Pleospora armeriae

Host Index—*Concluded*

Schizachne sp.
Mycosphaerella tassiana

Secale sp.
Claviceps purpurea
Erysiphe graminis

Sedum sp.
Mycosphaerella tassiana

Senecio spp.
Mycosphaerella punctiformis var. clematidis
Mycosphaerella tassiana
Pleospora compositarum
Pleospora oligasca

Shepherdia sp.
Sphaerotheca humuli

Sibbaldia sp.
Microthyrium arcticum
Mycosphaerella innumerella

Silene sp.
Leptosphaeria silenes-acaulis
Mycosphaerella tassiana
Pleospora comata

Sisyrinchium sp.
Mycosphaerella tassiana

Sitanion sp.
Mycosphaerella tassiana

Solanum sp.
Erysiphe cichoracearum

Solidago spp.
Erysiphe cichoracearum
Mycosphaerella tassiana
Pleospora balsamorrhizae

Sphenopholis sp.
Mycosphaerella tassiana

Spiraea sp.
Creonectria purpurea
Cryptodiaporthe macounii
Mycosphaerella tassiana

Stellaria sp.
Mycosphaerella tassiana

Stenanthium sp.
Mycosphaerella tassiana
Pleospora comata
Pleospora compositarum

Stipa sp.
Clathrospora pentamera
Clathrospora permunda
Mycosphaerella tassiana

Symphoricarpos sp.
Microsphaera diffusa
Mycosphaerella tassiana

Tanecetum sp.
Mycosphaerella tassiana
Pleospora herbarum

Taraxacum spp.
Sphaerotheca humuli var. fuliginea

Tofieldia sp.
Mycosphaerella tassiana
Pleospora herbarum var. occidentalis

Trifolium spp.
Cymadothea trifolii
Didymella trifolii
Erysiphe polygoni
Pleospora herbarum

Trisetum sp.
Leptosphaeria typharum
Mycosphaerella tassiana
Pleospora heleocharidis

Triticum sp.
Claviceps purpurea
Erysiphe graminis
Ophiobolus cariceti

Tsuga spp.
Dimerosporium tsugae
Herpotrichia nigra
Hypoxylon aspera

Typha sp.
Leptosphaeria eustoma
Leptosphaeria typhicola
Mycosphaerella typhae

Vaccinium spp.
Acanthorhynchus vaccinii
Melanomma pulvis-pyrius

Valeriana sp.
Sphaerella vagans

Vicia sp.
Melanospora papillata

Viola spp.
Pleospora asymmetrica
Sphaerotheca humuli

Vitis sp.
Guignardia bidwellii
Uncinula necator

Yucca sp.
Phomatospora argyrostigma

Zea sp.
Mycosphaerella tassiana

Zinnia sp.
Erysiphe cichoracearum

Zygadenus sp.
Mycosphaerella tassiana

CONTENTS OF VOLUME 31

ALLEN, O. N.—See Gregory, K. F.

ANDREAE, S. R.—See Andreae, W. A.

ANDREAE, W. A. and ANDREAE, S. R.—Studies on indoleacetic acid metabolism. I. The effect of methyl umbelliferone, maleic hydrazide, and 2, 4-D on indoleacetic acid oxidation, 426.

ATKINSON, R. G.—Survival and pathogenicity of *Alternaria raphani* after five years in dried soil cultures, 542.

BANNAN, M. W.—Further observations on the reduction of fusiform cambial cells in *Thuja occidentalis* L., 63.

BARR, M. E.—Pyrenomycetes of British Columbia, 810.

BASHAM, J. T., MOOK, P. V., and DAVIDSON, A. G.—New information concerning balsam fir decays in Eastern North America, 334.

BELL, H. P.—The growth cycle of the blueberry and some factors of the environment, 1.

BISHOP, C. J.—See MacDonald, R. E.

BLACKWOOD, A. C.—Production of cytases active on barley gum by bacteria of the genus *Bacillus*, 28.

BRADLEY, R. H. E. and GANONG, R. Y.—Note on the time potato leaf roll virus takes to pass from aphids on the leaves into the developing tubers, 143.

BREWER, D. and MACNEILL, B. H. Preliminary studies in *Ascochyta pisi* Lib., 739.

BRODIE, H. J. and GREGORY, P. H.—The action of wind in the dispersal of spores from cup-shaped plant structures, 402.

BURTON, M. O.—See Lochhead, A. G.

BURTON, M. O. and LOCHHEAD, A. G.—Nutritional requirements of *Arthrobacter terregens*, 145.

CALDER, J. A.—See Savile, D. B. O.

CHINN, S. H. F.—A slide technique for the study of fungi and actinomycetes in soil with special reference to *Helminthosporium sativum*, 718.

CORMACK, R. G. H. and GORHAM, A. L.—Effects of exposure to direct sunlight upon the development of leaf structure of two deciduous shrub species, 537.

DAVIDSON, A. G.—See Basham, J. T.

DENYER, W. B. G.—*Cephalosporium* canker of western hemlock, 361.

DUFF, G. H. and NOLAN, N. J.—Growth and morphogenesis in the Canadian forest species. I. The controls of cambial and apical activity in *Pinus resinosa* Ait., 471.

EGGERTSON, E.—An estimate of the number of alleles at the loci for heterothallism in a local concentration of *Polyporus obtusus* Berk., 750.

FORWARD, D. F.—The response of potato tubers to a period of anaerobiosis. I. Drifts in carbon dioxide production, 33.

FRASER, D. A. and MAWSON, C. A.—Movement of radioactive isotopes in yellow birch and white pine as detected with a portable scintillation counter, 324.

GANONG, R. Y.—See Bradley, R. H. E.

GARAY, L. A.—A new natural hybrid *Cypripedium* from Ontario, 660.

GORHAM, A. L.—See Cormack, R. G. H.

GREENIDGE, K. N. H.—Further studies of birch dieback in Nova Scotia, 548.

GREGORY, K. F. and ALLEN, O. N.—Physiological variations and host plant specificities of rhizobia isolated from *Caragana arborescens* L., 730.

GREGORY, P. H.—See Brodie, H. J.

GROVES, J. W.—See Skolko, A. J.

HAWN, E. J. and VANTERPOOL, T. C.—Preliminary studies on the sexual stage of *Rhizoctonia solani* Kühn, 699.

HUGHES, S. J.—Some foliicolous hyphomycetes, 560. Conidiophores, conidia, and classification, 577.

KAPICA, L.—See Pady, S. M.

KATZNELSON, H.—See Sutton, M. D.

KATZNELSON, H. and SUTTON, M. D.—Bacteriophage in relation to *Xanthomonas translucens*, 725.

KELLY, C. D.—See Pady, S. M.

KELLY, C. D. and PADY, S. M.—Microbiological studies of air over some nonartic regions of Canada, 90.

KEMP, W. G.—Studies on the physiology of *Elsinoe veneta*, 411.

LACHANCE, RENÉ-O. and PERRAULT, C.—Antagonisme des microorganismes du sol envers *Fusarium oxysporum* f. *lini*, agent de la flétrissure du lin, 515.

LANDERKIN, G. B.—A contrast technique for plaque counting, 142.

LEWIN, R. A. and MEINHART, J. O.—Studies on the flagella of algae. III. Electron micrographs of *Chlamydomonas moewussi*, 711.

LINDSAY, D. R.—See Moore, R. J.

LOCHHEAD, A. G.—See Burton, M. O.; Stevenson, I. L.

LOCHHEAD, A. G. and BURTON, M. O.—An essential bacterial growth factor produced by microbial synthesis, 7.

LUDWIG, R. A.—See Sampson, R. E.

MACDONALD, R. E. and BISHOP, C. J.—A further survey of plants for antibacterial substances. 123.

MCGINNIS, R. C.—Cytological studies of chromosomes of rust fungi. I. The mitotic chromosomes of *Puccinia graminis*, 522.

MCKEEN, W. E.—Preliminary studies of root and basal stalk rot of maturing corn in Ontario, 132.

MACNEILL, B. H.—See Brewer, D.

MAWSON, C. A.—See Fraser, D. A.

MEINHART, J. O.—See Lewin, R. A.

MOOK, P. V.—See Basham, J. T.

MOORE, R. J. and LINDSAY, D. R.—Fertility and polyploidy of *Euphorbia cyparissias* in Canada, 152.

MOSS, E. H.—Forest communities in Northwestern Alberta, 212. Marsh and bog vegetation in Northwestern Alberta, 448.

NEISH, A. C.—Studies on the anaerobic dissimilation of glucose by *Bacillus subtilis* (Ford's type), 265.

NEWTON, J. D.—See Spencer, J. F. T.

NEWTON, WM.—Antagonism by species of *Alternaria* and the isolation of a crystalline substance from the filtrate of cultures of *A. radicina*, 423.

NOBLES, M. K.—Studies in wood-inhabiting hymenomycetes. I. *Odontia bicolor*, 745.

NOLAN, N. J.—See Duff, G. H.

PADY, S. M.—See Kelly, C. D.

PADY, S. M. and KAPICA, L.—Air-borne fungi in the Arctic and other parts of Canada, 309.

PADY, S. M. and KELLY, C. D.—Studies on microorganisms in Arctic air during 1949 and 1950, 107.

PERRAULT, C.—See Lachance, René-O.

PERSON, C.—Observations on interphase and prophase nuclei of root tips of Einkorn wheat and onion, 527.

PODMORE, D. G.—See Thomas, G. P.

POTZGER, J. E.—Nineteen bogs from Southern Quebec, 383.

ROBERTS, D. W. A.—Physiological and biochemical studies in plant metabolism. VIII. The distribution of invertase in the first leaf of Khapli wheat, 367.

ROUATT, J. W.—See Stevenson, I. L.

SAMPSON, R. E. and LUDWIG, R. A.—The effectiveness of certain fungicides against *Botrytis tulipae* (Lib.) Lind, 531.

SAVILE, D. B. O.—Notes on boreal Ustilaginales, 663.

SAVILE, D. B. O. and CALDER, J. A.—Phylogeny of *Carex* in the light of parasitism by the smut fungi, 164.

SKOLKO, A. J. and GROVES, J. W.—Notes on seed-borne fungi. VII. *Chaetomium*, 779.

SPENCER, J. F. T. and NEWTON, J. D.—Factors influencing the growth and survival of rhizobia in humus and soil cultures. II, 253.

STEVENSON, I. L. and LOCHHEAD, A. G.—The use of a percolation technique in studying antibiotic production in soil, 23.

STEVENSON, I. L. and ROUATT, J. W.—Qualitative studies of soil microorganisms. XI. Further observations on the nutritional classification of bacteria, 438.

STOVER, R. H.—The effect of soil moisture on *Fusarium* species, 693.

SUTTON, M. D.—See KATZNELSON, H.

SUTTON, M. D. and KATZNELSON, H.—Isolation of bacteriophages for the detection and identification of some seed-borne pathogenic bacteria, 201.

TAMBOLINE, F. R.—Nitrogen and vitamin requirements of *Pseudomonas hydrophila*, 206.

THOMAS, G. P. and PODMORE, D. G.—Studies in forest pathology. XI. Decay in black cottonwood in the middle Fraser region, British Columbia, 675.

VANTERPOOL, T. C.—See Hawn, E. F.

WARD, G. M.—The isolation and identification of sucrose from the seedling wheat leaf, 75. Physiological and biochemical studies in plant metabolism. VII. The invertase of the seedling wheat leaf, 81.

WENSLEY, R. N.—Microbiological studies of the action of some selected soil fumigants, 277.

WERESUB, L. K.—Studies of Canadian Thelephoraceae. X. Some species of *Peniophora*, section *Tubuliferae*, 760.

WHITE, L. T. Studies in forest pathology. X. Decay of white pine in the Timagami Lake and Ottawa Valley areas, 175.

CORRECTION

Page 206. In Footnote 1 "Issued as Paper No. 000....." should read "Issued as paper No. 146.....".

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Contents

Page

Preliminary Studies on the Sexual Stage of *Rhizoctonia solani* Kühn—*E. J. Hawn and T. C. Vanterpool* - - - - - - - - 699

Studies on the Flagella of Algae. III. Electron Micrographs of *Chlamydomonas moewusii*—*R. A. Lewin and Josephine O. Meinhart*** - - - - - 711

A Slide Technique for the Study of Fungi and Actinomycetes in Soil with Special Reference to *Helminthosporium sativum*—*S. H. F. Chinn*** - - 718

Bacteriophage in Relation to *Xanthomonas translucens*—*H. Katznelson and M. D. Sutton*** - - - - - - - - - - - - 725

Physiological Variations and Host Plant Specificities of Rhizobia Isolated from *Caragana arborescens* L.—*K. F. Gregory and O. N. Allen*** - - 730

Preliminary Studies in *Ascochyta pisi* Lib.—*Donald Brewer and Blair H. MacNeill*** - - - - - - - - - - - - 739

Studies in Wood-inhabiting Hymenomycetes. I. *Odontia bicolor*—*Mildred K. Nobles*** - - - - - - - - - - - - - - 745

An Estimate of the Number of Alleles at the Loci for Heterothallism in a Local Concentration of *Polyporus obtusus* Berk.—*E. Eggertson*** - - 750

Studies of Canadian Thelephoraceae. X. Some Species of *Peniophora*, Section *Tubuliferae*—*Luella K. Weresub*** - - - - - - - 760

Notes on Seed-borne Fungi. VII. *Chaetomium*—*A. J. Skolko and J. W. Groves*** - - - - - - - - - - - 779

Pyrenomycetes of British Columbia—*Margaret E. Barr* - - - - 810

Contents of Volume 31 - - - - - - - - - - - - - - 831